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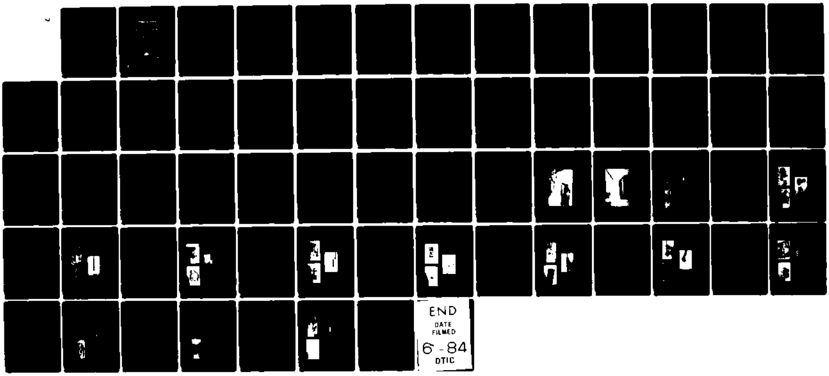

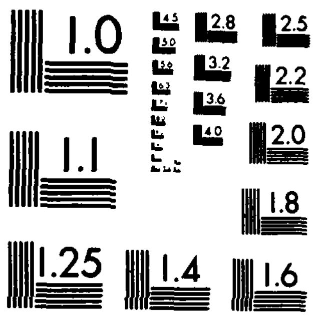

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Review 1-84

AEROMEDICAL REVIEW

VISIBLE-LIGHT RESIN CURING UNITS

Laurence P. Crigger, Major, USAF, DC
Michael A. Morris, Captain, USAF, BSC
Kenneth Broadwell, Senior Airman, USAF
John M. Young, Colonel, USAF, DC

March 1984

USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

NOTICES

This final report was submitted by personnel of the Dental Investigation Service Branch, Clinical Sciences Division, USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas, under job order DSB38200.

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The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

Laurence P. Crigger

LAURENCE P. CRIGGER, Major, USAF, DC
Project Scientist

John M. Young

JOHN M. YOUNG, Colonel, USAF, DC
Supervisor

Royce Moser, Jr.

ROYCE MOSER, Jr.
Colonel, USAF, MC
Commander

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This document presents the principle of visible-light activated composite resins and the advantages of visible-light vs. ultraviolet light activation. Twelve units are compared on the basis of: cost; size and portability; length of cord; diameter of curing tip; method of cooling; voltage regulation; timer functions and accuracy; method of light transmission; location of controls; method of activation; depth of cure; possible hazards; evaluation of medical maintenance; and special features. Guidelines for use and selection are provided.

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Laurence P. Crigger, Major, USAF, DC	(512) 536-3502	USAFSAM/NGD

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VISIBLE-LIGHT RESIN CURING UNITS

INTRODUCTION

Visible-light cured resins, the latest advance in the field of dental composites, are an outgrowth of the ultraviolet (UV)-light cured resins. In general, visible-light cured resins are single paste systems possessing photoinitiators that absorb light in the 420- to 450-nm range, and induce polymerization by producing free radicals. The light generators used to initiate polymerization (or curing) offer several advantages over the first generation UV lights.

Polymerization with visible light results in a greater and more consistent depth of cure, which extends even into undercuts and through enamel. Concerns about health hazards are fewer than with UV light. Finally, the intensity of the lamp remains constant throughout its life. Like any incandescent bulb, failure occurs all at once and not over a period of time. Thus, a more stable and predictable depth of cure is possible throughout the life of the bulb.

The purpose of this Aeromedical Review is to help base dental surgeons decide which visible-light resin curing unit will best suit their needs.

TEST AREAS AND EVALUATION

For each of the 12 units, designated as A to L, a protocol identified 14 specific areas to be evaluated: (1) cost; (2) size, weight, and portability; (3) length of cord; (4) diameter of curing tip; (5) method of cooling; (6) voltage regulation; (7) timer functions; (8) method of light transmission; (9) location of controls; (10) method of activation; (11) depth of cure; (12) possible hazards, intensity, and wavelength; (13) maintenance evaluation; and (14) special features.

The 12 units and their manufacturers are listed here:

Unit	Manufacturer
A. Command	Kerr Manufacturing P.O. Box 455 Romulus MI 48174 (800) 521-2854
B. Elipar	ESPE/Premier P.O. Box 111 Norristown PA 19404 (215) 277-3800

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Unit	Manufacturer
C. Fiber-Lite	Dolan-Jenner Industries Blueberry Hill Industrial Park P.O. Box 1020 Woburn MA 01801 (617) 935-7444
D. Heliomat	Vivadent USA P.O. Box 304 Tonawanda NY 14150 (716) 694-2333
E. The Initiator	Solid State Systems 2006 - 196th S.W. Un.K. Lynwood WA 98036 (800) 426-1309
F. Insight II	American Midwest 901 W. Oakton St. Des Plaines IL 60018 (312) 640-4800
G. Kavo/Vicon "DLS"	Kavo American Corporation 2200 W. Higgins Road Hoffman Estates IL 60195 (312) 885-3855
H. Optilux	Demetron Research Corp. 5 Ye Olde Road Danbury CT 06810 (203) 748-0030
I. Prisma-Lite	L. D. Caulk Co. Lakeview and Clark Ave. Milford DE 19963 (800) 441-8448
J. Spectra-Lite	Pentron Corp. P.O. Box 771 Wallingford CT 06492 (203) 265-3886
K. Translux	Kulzer Inc. 25251 Pasea de Alicia Suite 200 Laguna Hills CA 92653 (800) 854-4003
L. Visar 2	Den Mat P.O. Box 1759 Santa Maria CA 93456 (800) 235-2441

Each of the 14 test areas, with their respective results (refer to Table 1, p.30), are presented and discussed sequentially throughout this *Aeromedical Review*:

1. Cost

All prices are current as of March 1984. Prices may vary from those stated, and may include a supply of the respective manufacturer's resin material. All listed prices represent the government price of the unit alone:

Unit	Price
C	$198.00
F	$219.00[a]
A	$327.60
E	$387.00
L	$365.75
I	$400.00
H	$409.50
J	$450.00
G	$479.00
B	$486.85
D	$499.15
K	$500.00

[a] Cost of retrofitting existing light boxes.

2. Size, Weight, and Portability

In many Air Force dental clinics, these units (with the exception of "fixed units") will be used in multiple Dental Treatment Rooms (DTRs). Because the units will be transported from room to room as the need arises, portability is a desired feature. The physical dimensions of the unit may also be a factor to consider if space in the DTR is limited. Presented here is information concerning each unit, its size, and its portability:

Unit	Size Width x height x depth	Weight (lb)	Handle
H	4-1/4 x 2-3/4 x 4-1/2 in. plus gun 10.8 x 6.98 x 11.4 cm plus gun	2.8	No
B	5 x 3 x 8 in. plus gun 12.7 x 7.62 x 20.3 cm plus gun	4.5	No
C	5 x 3-3/4 x 8 in. 12.7 x 9.53 x 20.3 cm	6.0	Yes
F[a]	5 x 5 x 14 in. 12.7 x 12.7 x 32.8 cm	5.75	No
G[a]	5 x 4 x 12-1/2 in. 12.7 x 10.2 x 31.2 cm	6.3	No
L	5-3/4 x 5-1/2 x 9-1/4 in. 14.6 x 13.9 x 23.5 cm	6.5	Yes
E	8-1/4 x 3 x 9-1/2 in. 20.9 x 7.62 x 24.1 cm	7.0	Yes
A	7 x 6 x 8 in. 17.8 x 15.2 x 20.3 cm	7.4	Yes
K	8-1/2 x 3-3/4 x 8-1/2 in. 21.6 x 9.5 x 21.6 cm	10.0	No
J	9-1/2 x 3-1/2 x 9 in. 24.1 x 8.89 x 22.9 cm	10.5	No
D	10-1/2 x 4-1/2 x 8-1/2 in. 26.7 x 11.4 x 21.6 cm	13.0	No
I	11-1/4 x 5 x 12 in. 28.6 x 12.7 x 30.5 cm	17.0	No

[a] Units not designed to be portable.

3. Length of Cord

Lengths were measured from the unit itself to the tip of the curing wand (or handle of the gun). These lengths represent the maximum linear distance the unit can be placed from the working area:

Unit	Length
H	44 to 70 in. (111.7 to 177.8 cm)[coiled cord]
C	48 in. (121.9 cm)
F[a]	48 or 72 or 120 in. (121.9 or 182.9 or 304.8 cm)
L	49 in. (124.5 cm)
K	58 in. (147.3 cm)
A	60 in. (152.4 cm)
I	65-1/2 in. (166.4 cm)
B	68 in. (172.7 cm)
J	69 in. (175.3 cm)
E	74-1/2 in. (189.2 cm)
D	77 in. (195.6 cm)
G[a]	84 to 168 in. (213.4 to 426.7 cm)[variable]

[a] Fixed units; extra length necessary to traverse delivery arm of dental unit.

4. Diameter of Curing Tip

The diameter of the curing tip will have some bearing on the area of the resin that is exposed; for if the distance from the surface of the resin to the curing wand remains constant, a larger diameter tip will expose a larger segment of resin:

Unit	Diameter of tip (including metal or plastic housing)	Diameter of bundles
B	0.409 in. (9.57 mm)	0.312 in. (7.31 mm)
H	0.355 in. (8.31 mm)	0.310 in. (7.25 mm)
K	0.304 in. (7.11 mm)	0.270 in. (6.32 mm)
L	0.310 in. (7.25 mm)	0.265 in. (6.20 mm)
C	0.304 in. (7.11 mm)	0.226 in. (5.28 mm)
J	0.236 in. (5.52 mm)	0.209 in. (4.89 mm)

Unit	Diameter of tip (including metal or plastic housing)	Diameter of bundles
I	0.262 in. (6.13 mm)	0.200 in. (4.68 mm)
D,G	0.248 in. (5.8 mm)	0.200 in. (4.68 mm)
E	0.305 in. (7.14 mm)	0.199 in. (4.66 mm)
A	0.363 in. (8.49 mm)	0.182 in. (4.25 mm)

NOTE: Unit F is not included here.

5. Method of Cooling

Units A, B, C, D, E, F, G, H, J, K, and L use a fan. Unit I uses heat sink.

6. Voltage Regulation

Because line voltage can fluctuate, a voltage regulator is considered an advantageous feature. It will sense peaks and valleys and will adjust the voltage accordingly, so that output remains fairly constant. Only units B, D, E, and I have voltage regulators.

7. Timer Functions and Accuracy

Several methods are employed to control the activation of the curing light. Some units employ a timer that the operator sets, some emit audible tones at fixed intervals, and others have internal switches that break the circuit after a certain length of time. Timer features are listed next:

Units With Timers

A. Variable timer, 10 - 30 sec

D. Variable timer, 10 sec to infinity

E. Paddle-wheel, 10-, 20-, 30-, 40-, 50-, 60-sec stops; also has tone and L.E.D indicator lamp

F. Variable timer, 2 - 60 sec

J. Click stops at 10-, 20-, 30-, 40-, 50-, 60-sec and infinity.

Units With Audible Tones Only

H. Every 10 sec (as long as trigger is depressed)

I. Every 10 sec (as long as button is depressed)

K. Every 20 sec

L. Every 20 sec

Units With Automatic Shut-Off

B. After 20 sec

Units With Other Than Foregoing Features

C. No timer, no audible tone. Controlled by power on/off only

For each unit with a timer, controls were set at specific times--and five trials were run, timed with a stopwatch, and then averaged. Timing was started when the light came on, and stopped when the light shut off. For units with audible tones, timing was measured from tone to tone. Averages were compared to the setting or stated time interval. Postive values indicate the measured time exceeded the setting or stated interval; negative values indicate the opposite. This information is summarized in the following lists:

Unit	Setting or Interval	Actual					Average	Variance
A	10	10	10	10	10	10	10	0
	20	23	22	22.5	22.5	22.5	22.5	+2.5
	30	30	29.5	30	30	30	29.9	-0.1
B	20	22	22	22	22.1	22.1	22.04	+2.04

Unit	Setting or Interval	Actual					Average	Variance
D	10	11	11	11	11	11	11	+1.0
	20	21	21	21	21	21	21	+1.0
	30	32	32	32	32	32	32	+2.0
	40	43.2	43.2	43	43.2	43.2	43.16	+3.16
	50	53.5	53	53	53.1	53	53.12	+3.12
	60	64.5	64.8	64.5	64.5	64.5	65.56	+5.56
E	10	9.8	9.5	9.8	9.5	9.5	9.62	-0.38
	20	19	19	19	19.2	19	19.04	-0.96
	30	28.2	28	28	28	28	28.04	-1.96
	40	37	37	37	37	36.8	36.96	-3.04
	50	46	46	45.8	46	46	45.96	-4.04
	60	55	54.5	54.8	55	55	54.92	-5.08
F	10	10.2	10	10	10	10	10.04	+0.04
	20	21	20.8	20.8	21	21	20.92	+0.92
	30	30.5	31	30.2	31	31	30.74	+0.74
	40	41	39.8	39.8	39.8	39.8	40.14	+0.14
	50	49	51	50	50.8	50	50.16	+0.16
	60	56	58.2	57.8	58.2	58	57.64	-2.36
H	10	15	11	11	12	11	12	+2.0
I	10	10	10	10	10	10	10	0

Unit	Setting or Interval	Actual					Average	Variance
J	10	10	10	10	10	10	10	0
	20	20.2	20.2	20	20	20	20.08	+0.08
	30	30.8	30	30	30	30	30.16	+0.16
	40	40.5	40.5	40.5	40.5	40.8	40.56	+0.56
	50	51	50.8	50.8	51	51	50.92	+0.92
	60	61	61	62	61.5	61.2	61.34	+1.34
K	20	23	24	24	23.2	24	23.64	+3.64
L	20	17	17.2	17	17	17	17.04	-2.96

8. Method of Light Transmission

Units A, C, D, E, F, G, I, J, and L employ bundles of glass rods (fiber optics) to transmit light to the tip of the curing wand. Units B and H use a single glass rod, respectively, while Unit K uses a fluid-filled, reinforced cord.

9. Location of Controls

This information is presented in the following lists:

Unit	Front Panel	Rear Panel	Wand/Gun	Other
A	Power On/Off Timer/Activator			
B	Power On/Off		Activator trigger	
C	Power On/Off Intensity control			
D	Power On/Off Timer selector Auxiliary call-up Multifunction knob		Activator switch	

Unit	Front Panel	Rear Panel	Wand/Gun	Other
F	Power On/Off Touch control		Activator button	Remote timer
G	Timer			
H	Power On/Off		Activator trigger	
I	Power On/Off		Activator button	
J	Power On/Off Timer Call-up button Remote On/Off		Activator sensor	
K	Activator button	Power On/Off		
L	Power On/Off Intensity control			

10. Method of Activation

Only six units (B, D, F, H, I and J) allow the operator to activate the light at the handpiece. However, two of these units (H and I) require the operator to maintain pressure on the trigger or button in order to keep the light on; audible tones provide the timing function. One unit (G) operates from the dental unit's pilot or drive air pressure, and is activated via the foot control that also operates the high-speed and low-speed handpieces. For all other units (A, C, E, K, and L), the operator must press a button or flip a switch at the console, and then position the wand. Three units (A, D, and E) have a delay feature to allow the operator to make this maneuver before the light comes on.

11. Depth of Cure

Depth of cure was evaluated (Figs. 1 and 2) in the following manner: Teflon dies were constructed in thicknesses of 2, 3, 4, 5, and 6 mm; and a 5-mm diameter hole was drilled in the center of each die. A glass mixing slab was placed over a piece of white paper. For each test, a die was placed on the glass slab with a strip of clear mylar in between the two. Then a light cured resin (Silux - 3M Company, St. Paul MN) was packed into the center hole, against the mylar strip, and the "well" was filled to a slight excess. Another mylar strip was placed over the resin, and a second glass slab was used to flatten out the resin to insure a uniform thickness. The

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EDITOR'S NOTE: For the convenience of the reader, all of the figures in this *Aeromedical Review* have been grouped at the close of the publication.

tip of the curing wand was positioned 1 mm from the top surface of the resin, and was secured in place with clamps. The light was activated for a specific time (10, 20, 30, 40, 50, or 60 sec) for each size die and for each light tested. Timing was controlled with a stopwatch. Fresh resin was used for each individual test. After curing, the top surface of the resin "pellet" was compared to the bottom surface with a #2 dental explorer. Each surface was scored as follows:

1 = smooth, glassy, hard to scratch;
2 = hard but surface easily scratched and/or chipped; and
3 = soft and easily penetrated.

If both surfaces were scored "1," the resin was considered completely polymerized in the given time interval. A higher score was considered not polymerized. A total of 30 tests were conducted on each light. Scores are expressed as a fraction--top surface score over bottom surface score; e.g., 1/1 or 1/2. Results are listed next:

Unit	Thickness	10 sec	20 sec	30 sec	40 sec	50 sec	60 sec
A	2 mm	1/3	1/2	1/1	1/1	1/1	1/1
	3 mm	1/3	1/3	1/2	1/2	1/1	1/1
	4 mm	1/3	1/3	1/3	1/3	1/2	1/1
	5 mm	1/3	1/3	1/3	1/3	1/3	1/3
	6 mm	1/3	1/3	1/3	1/3	1/3	1/3
B	2 mm	1/3	1/1	1/1	1/1	1/1	1/1
	3 mm	1/3	1/2	1/1	1/1	1/1	1/1
	4 mm	1/3	1/3	1/2	1/2	1/1	1/1
	5 mm	1/3	1/3	1/3	1/3	1/3	1/3
	6 mm	1/3	1/3	1/3	1/3	1/3	1/3
C	2 mm	1/3	1/2	1/1	1/1	1/1	1/1
	3 mm	[illegible]	1/2	1/2	1/2	1/1	1/1
	4 mm	[illegible]	1/3	1/3	1/2	1/2	1/1
	5 mm	[illegible]	1/3	1/3	1/3	1/3	1/3
	6 mm	1/3	1/3	1/3	1/3	1/3	1/3

NOTE: Blocked scores indicate times required for complete polymerization for specific thicknesses of resin.

Unit	Thickness	10 sec	20 sec	30 sec	40 sec	50 sec	60 sec
D	2 mm	1/3	1/2	1/1	1/1	1/1	1/1
	3 mm	1/3	1/3	1/3	1/1	1/1	1/1
	4 mm	1/3	1/3	1/3	1/3	1/2	1/1
	5 mm	1/3	1/3	1/3	1/3	1/3	1/3
	6 mm	1/3	1/3	1/3	1/3	1/3	1/3
E	2 mm	2/3	1/2	1/2	1/2	1/1	1/1
	3 mm	2/3	1/3	1/3	1/3	1/2	1/2
	4 mm	2/3	1/3	1/3	1/3	1/3	1/3
	5 mm	2/3	1/3	1/3	1/3	1/3	1/3
	6 mm	2/3	1/3	1/3	1/3	1/3	1/3
F	2 mm	2/3	1/2	1/2	1/1	1/1	1/1
	3 mm	2/3	1/3	1/2	1/2	1/1	1/1
	4 mm	2/3	1/3	1/3	1/3	1/2	1/2
	5 mm	2/3	1/3	1/3	1/3	1/3	1/3
	6 mm	2/3	1/3	1/3	1/3	1/3	1/3
G	2 mm	2/3	1/3	1/2	1/1	1/1	1/1
	3 mm	2/3	1/3	1/3	1/2	1/2	1/1
	4 mm	2/3	1/3	1/3	1/3	1/3	1/3
	5 mm	2/3	1/3	1/3	1/3	1/3	1/3
	6 mm	2/3	1/3	1/3	1/3	1/3	1/3
H	2 mm	1/2	1/1	1/1	1/1	1/1	1/1
	3 mm	1/3	1/3	1/2	1/1	1/1	1/1
	4 mm	1/3	1/3	1/3	1/2	1/2	1/1
	5 mm	1/3	1/3	1/3	1/3	1/2	1/2
	6 mm	1/3	1/3	1/3	1/3	1/3	1/3

Unit	Thickness	10 sec	20 sec	30 sec	40 sec	50 sec	60 sec
I	2 mm	1/3	1/2	1/1	1/1	1/1	1/1
	3 mm	1/3	1/2	1/2	1/1	1/1	1/1
	4 mm	1/3	1/3	1/2	1/2	1/1	1/1
	5 mm	1/3	1/3	1/3	1/3	1/3	1/2
	6 mm	1/3	1/3	1/3	1/3	1/3	1/3
J	2 mm	1/3	1/2	1/1	1/1	1/1	1/1
	3 mm	1/3	1/3	1/2	1/2	1/1	1/1
	4 mm	1/3	1/3	1/3	1/3	1/1	1/1
	5 mm	1/3	1/3	1/3	1/3	1/3	1/3
	6 mm	1/3	1/3	1/3	1/3	1/3	1/3
K	2 mm	1/3	1/2	1/1	1/1	1/1	1/1
	3 mm	1/3	1/2	1/2	1/1	1/1	1/1
	4 mm	1/3	1/3	1/3	1/2	1/2	1/1
	5 mm	1/3	1/3	1/3	1/3	1/3	1/3
	6 mm	1/3	1/3	1/3	1/3	1/3	1/3
L	2 mm	1/3	1/2	1/1	1/1	1/1	1/1
	3 mm	1/3	1/3	1/2	1/1	1/1	1/1
	4 mm	1/3	1/3	1/3	1/3	1/2	1/1
	5 mm	1/3	1/3	1/3	1/3	1/3	1/3
	6 mm	1/3	1/3	1/3	1/3	1/3	1/3

To summarize, only two Units (B and H) completely polymerized a 2-mm sample of Silux in 20 sec. Unit E required 50 sec; and Units F and G,

40 sec, respectively. The remaining Units (A, C, D, I, J, K, and L) required 30 sec. No unit would polymerize a 2-mm sample in 10 sec.

12. Possible Hazards, Intensities, and Wavelengths

Early resin curing units produced a significant amount of UV light. Food and Drug Administration investigations have shown that this type of radiation can be hazardous to the eye. Although the peak output of the current generation of curing units is in the visible band of the electromagnetic spectrum, and the UV output is greatly reduced, other types of ocular hazards may be present.

Contrary to UV light, whose potential hazard is primarily to the cornea of the eye, visible-light curing units should produce their effects--if any--on the retina. The shift from UV to visible light results in much greater levels of retinal irradiation, because less light is absorbed by the media of the eye. In addition, the eye's visual photoreceptors are quite sensitive to energy in this band of the spectrum. Also, light not absorbed by retinal sensory elements will be absorbed by the pigmented epithelium of the retina,thus causing localized rises in temperature. Hence, if the light is intense enough, both photochemical and thermal damage to the eye may result.

Potential hazards of visible-light curing units can be related to three bands of the electromagnetic spectrum: (a) The first is the UV hazard. Since all of the units tested had insignificant UV output, this particular hazard is nonexistent. (b) The second is the blue light hazard. Its effects are due to photochemical reactions, and peak at approximately 440 nm, and are absent for wavelengths longer than 500 nm. (c) The third type is a thermal hazard that also peaks at 440 nm, but extends well into the infrared region to at least 1500 nm.

Two systems exist for measuring light: radiometry and photometry. Radiometry measures the energy of light entering a detector, but photometry assesses that energy according to its effectiveness at stimulating a visual response. Thus the former method is quantitative (how much energy)-- and the latter is qualitative (how much brightness). Photometric measurements can be misleading because the body's visual system is quite insensitive at the extremes (blue and red), but very sensitive at midrange (green). Therefore, plotting photometric output versus wavelength may show little energy at short and long wavelengths when, in reality, the opposite may be true. For these reasons, radiometry is the method of choice.

Most standards establish maximum permissible exposure (MPE) levels according to the weighted spectral radiance of the source. This quantity is a measure of the power output, at each wavelength, per unit of solid angle of space. Each value is weighted according to a hazard factor, and these values are integrated to determine the MPE.

Each curing unit was measured on axis at a distance of two meters. For units with variable intensity, intensity was set at its highest output. A

Pritchard 1980b spectroradiometer (Photo Research, Division Kollmorgen, 3000 N. Hollywood Way, Burbank CA 91505) was used to measure spectral radiance from 400 nm to 730 nm in 10-nm increments. For infrared measurements, a black detector calorimeter--consisting of a black detector thermocouple connected to a Keithley 148 nanovoltmeter (Keithley Instruments, Inc, 28775-T Aurora Rd., Cleveland OH 44139)--was used to measure the energy output of the light. This measurement was made without filters between the light and detector, and with a Schott KG-3 infrared blocking glass filter (Schott Optical Glass, Inc., York Avenue, Duryea PA 18642) which blocks approximately 20% of the visible light. The data were then corrected. A Ralph Gerbands Co. shutter was used on the light. Several measurements were made for each condition, and a ratio of infrared energy to visible energy was calculated. By multiplying these ratios by the integrated visible spectral radiances measured with the Pritchard 1980b, the integrated spectral radiance was calculated.

The spectral radiance profiles of each light were weighed according to the potential of its component wavelengths to produce retinal damage. The resulting weighted integrated spectral radiances were then transformed by chronic hazard formulas into MPE durations. While the blue light hazard is independent of the area of the retina exposed, the thermal hazard equations contain a term which corrects for the area of the retinal image. The parameter used is the square of the angular subtense of the source in radians. A worse case distance of 10 in. (25 cm) was chosen, in which the same area of the retina was assumed to be chronically exposed. In reality, thermal hazard is possible only if one looks directly at the tip or a specular reflection of the tip (from a tooth for example).

Results: Integrated visible radiances (intensities) are listed next. These values represent the total visible energy produced by each unit. (Unit E was inoperable during this phase of the evaluation.)

Unit	Radiance (watts/sterim^2)
C	18,000
F	17,000
H	13,000
G	8,000
A	7,500
J	6,100
L	5,800
I	4,800
K	4,400
B,D	3,000

sterim^2 = steradian meters squared

The ratio of nonvisible output (primarily infrared) to visible light output for each unit is listed next. (Unit E was inoperable during this part of the evaluation.)

Unit	Ratio
D	0.00
B,H,K	0.04
J	0.50
G	0.56
I	0.65
C	0.95
F	1.20
L	1.30
A	2.40

MPEs for each unit, for blue light and thermal hazards, are listed next. These times represent the maximum safe cumulative exposure durations over a 24-hr period. Exposures accumulating to times less than those given here are considered below the threshold at which retinal damage occurs:

Unit	Blue light	Thermal hazards
A	8.9 min	31.0 min
B	7.9 min	>2 hr
C	4.3 min	6.0 min
D	10.5 min	>2 hr
F	12.0 min	6.5 min
G	7.8 min	5.7 min
H	2.4 min	23.0 min
I	6.2 min	2 hr
J	13.0 min	2 hr
K	31.0 min	1 hr
L	2 hr	47.0 min

Graphic displays for each unit are presented in Figures 3-25.

Discussion: Although the most effective band for curing is in the blue-green region of the electromagnetic spectrum, four units (A, F, G, and L) had peak outputs in the red or infrared bands. Two other units (C and I) had large infrared outputs, but peaked in the blue-green region. The rest of the units tested (B, D, H, J, and K) had very discrete output bands in the blue-green area. Interestingly, a wide variation occurred in integrated radiances (18,000 to 3,000).

None of the calculated hazard times appear short enough to be of practical concern. Because these lights are so bright, the possibility that one could accidentally view the output for even the lowest calculated time without averting the eyes appears unlikely. However, the glare can produce distracting afterimages that may cause momentary discomfort. The effects can be reduced by wearing tinted eyewear that absorbs blue and blue-green light; e.g., Argon laser protective goggles, available from: Glendale Optical Co, 130 Crossways Park Drive, Woodbury NY 11797 (Laser-Guard LGS-A Argon Goggles, $80.00); or American Optical, Safety Products Division, Southbridge MA 01550 (Product Code 40708, Catalog Number 598, $82.00).

In summary, very little hazard is associated with the use of these light curing units. By avoiding prolonged viewing and by wearing the properly tinted eyewear, one can reduce the hazard and/or discomfort to almost nil.

13. Evaluation by Biomedical Equipment Maintenance Personnel

By the use of the following categories, all units were evaluated:

a. AVAILABILITY OF LITERATURE

(1). Operator manuals
(2). Service manuals and schematics
(3). Repair parts breakdown

b. OPERATOR AND PATIENT SAFETY: Unit properly grounded

c. DURABILITY OF UNIT

(1). Material and quality of construction
(2). Design quality
(3). Connection type for fiber optic cable
(4). Life expectancy of fiber optic cable

d. ACCESSIBILITY AND QUALITY OF INTERNAL COMPONENTS FROM A MAINTENANCE VIEWPOINT

(1). Quality of printed circuit boards
(2). Assure that components are marked and that they can be cross-referenced if replacement is necessary
(3). Assure that components can be removed or replaced easily

(4). Units fused with external access
(5). Assure that power cord has strain relief

e. BULB TYPE

f. WARRANTY

g. COMMENTS

Unit A: Command

a.(1). Operator's sheet instructions included with unit
(2). Not available
(3). Not available

b. Unit is properly grounded: ground connection from hospital grade plug to internal chassis

c.(1). Metal cabinet--cheaply made
(2). Poor design--very difficult to get to inside of unit because case and chassis riveted together
(3). Plug-in type connector--loose--could easily be pulled out by accident or possibly during use
(4). Five (5) years under normal use

d.(1). Cannot be assessed due to inaccessibility of unit's interior
(2). Same as (1)
(3). Much difficulty to maintain due to inaccessibility
(4). Unit has fuse with external access
(5). Unit power cord does have strain relief

e. Quartz-halogen with spectral output of 375 to 575 nm

f. One year on everything, except bulb

g. Fiber-optic cable of medium flexibility: Due to unavailable literature and inaccessibility of unit, would be very difficult and time consuming to work on.

Unit B: Elipar

a.(1). Operator's manual included with unit
(2). Unavailable
(3). Unavailable

b. Unit properly grounded: ground from plug to internal chassis

c.(1). Unit is well made; metal cabinet
(2). Cabinet designed well, but problems inside

(3). Permanent power cord with strain relief from unit to light source in handpiece
(4). Unit does not use fiber optics

d.(1). Good quality printed circuit boards
(2). Printed circuit boards and components are marked; however, only small amount of components could be cross-referenced
(3). Would require vast amounts of desoldering to remove printed circuit boards and components; time consuming
(4). Unit is fused internally; requires removal of cover to replace; unit has thermal protector
(5). External connection for power cord, detachable

e. Ellipsoid-halogen bulb with spectral output of 400 to 480 nm

f. One-year warranty on entire unit, except bulb

g. Difficult to repair in field due to unavailability of necessary literature. Company doesn't want anyone other than its servicemen to repair unit.

<u>Unit C</u>: Fiber-Lite

a. All literature included with unit

b. Unit is properly grounded: ground connection from molded plug to internal chassis

c.(1). Metal case; quality of construction fair; inexpensive
(2). Design quality good for internal access; light loss around sides of case
(3). Plug-in type connector, with tightening screw; some light loss around connection
(4). Two to three years with normal use

d.(1). No printed circuit boards
(2). Unit includes transformer, light, fan, switch, and rheostat
(3). Parts could be easily removed for replacement
(4). Unit is not fused
(5). Power cord does not have strain relief

e. Quartz-halogen type with spectral output of 400 to 480 nm

f. One-year warranty except bulb

g. Unit is simple and would be easy to repair in field due to simplicity. Seems to be dependable, inexpensive unit. Fiber-optic cable offers a slight resistance to hand movements.

Unit D: Heliomat

a.(1). Operator manual included with unit
(2). Service manual and schematics will be available in future
(3). Will be available; repair parts breakdown awaiting UL approval

b. Unit is properly grounded: ground connection from hospital grade plug to internal chassis

c.(1). Sturdy metal construction; well made unit with many internal features to make repair easier
(2). Excellent design quality, internal and external
(3). External plug-in type connector for fiber optics. Keyed to prevent improper installation. Some light loss around bottom of unit and side covers
(4). Three-year life expectancy (will be extended in near future due to new improved cable)

d.(1). Good quality printed circuit boards, all circuit runs on one side of board
(2). Components and printed circuit boards marked; all components can be cross-referenced for substitution
(3). Boards are easily removed, thus giving easy access to components
(4). Unit is fused with external access; unit also has an automatic thermo cut-out switch that protects unit from overheating
(5). Power cord has strain relief

e. Halogen bulb with unknown spectral output

f. Presently 6 months, will be changed to one year except for bulb

g. Fiber-optic cable is very flexible and can easily be used. Unit can be used for polymerization as well as diagnostic purposes. Unit would be repairable in field, due to accessibility and availability of literature. Slide switch on handpiece is fiber-optic controlled instead of electrically controlled, thus eliminating hazard to patient or operator.

Unit E: The Initiator

a.(1). Operator's manual included
(2,3). Could be obtained; but manufacturer prefers that customer send unit to factory for repair

b. Unit is properly grounded: ground connection from hospital grade plug to internal chassis

c.(1). Metal cabinet; good quality cons ruction
(2). Good design quality, inside and out
(3). Plug-in type connection; locks into place
(4). Two or more years under normal use

d.(1). Good quality printed circuit boards
(2). Boards and components marked and can be cross-referenced
(3). Components can be easily removed
(4). Unit is fused with external access; also contains thermal protection switch
(5). Power cord connects externally to rear of unit; detachable

e. Quartz-halogen with spectral range of 400 to 475 nm

f. Two-year warranty

g. Unit has delay feature which enables operator to position wand before it turns on; fiber-optic cable offers slight resistance.

Unit F: Insight II

a.(1). Operator and installation manuals included with unit
(2). Service manuals and schematics unavailable; company does not give out this information
(3). No parts breakdown

b. Unit properly grounded: ground connection from hospital grade plug to internal chassis

c.(1). Sturdy metal construction
(2). Good design quality; unit is small and adaptable
(3). Fiber optics plug into a port, and are held in place by small set screw. Port plugs are provided to cover unused ports. No noticeable leakage of light.
(4). Approximately 2 to 3 years, with normal use

d.(1). Good quality printed circuit boards; runs on same side of board; easily traced
(2). Components are marked, and most could be cross-referenced
(3). Components can be removed or replaced easily
(4). Unit is not fused, but contains thermal protector
(5). Power cord provided with strain relief

e. Bulb is tungsten-halogen type with spectral output of about 470 nm

f. Light source has one-year warranty except for bulb. Handpieces and wands have separate warranties.

g. Unit features automatic touch activation of light. Light wand comfortable in hand; handle does not offer resistance to

operator movement. After breakdown, unit would be difficult to repair in field without service manuals, schematics, or repair parts list.

Unit G: Kavo/Vicon "DLS"

a. Literature unavailable at present; unit not in full production

b. Unit is properly grounded: grounding pin from plug to internal chassis.

c.(1). Unit constructed of metal and is durable
(2). Design quality good for unit is air-operated, so that the operator does not have to control unit at the console. Unit is activated by foot switch.
(3). Plug-in type connector. No light loss around connector itself; however, minor loss around ends of cabinet.
(4). Depends entirely on use

d.(1). No printed circuit boards are used here
(2). The only components are switches, solid-state relays, and capacitors. All are marked and easily identified
(3). Removal of components difficult and time consuming due to inaccessibility. Internally, parts and components are very crowded. Wiring is usually soldered instead of using terminal strips, thus making connections and disconnections difficult
(4). Unit is not fused
(5). Power cord does have strain relief

e. Halogen bulbs with spectral output of 400 to 480 nm

f. One year warranty

g. From a maintenance viewpoint, unit would be difficult to repair in field. Due to the small number of electrical components, however, malfunction should be minimal.

Unit H: Optilux

a.(1). Included with unit
(2,3). Not normally included, but could be obtained

b. Unit properly grounded: connected from grounding pin to internal chassis

c.(1). Metal and plastic materials used for construction; well built

(2). Exterior is of good quality; interior is of poor quality Would be difficult to repair due to component placement (overcrowded)
(3). Fiber optics in handpiece; electrical cable from unit to handpiece
(4). Fiber-optic life increased due to no cable; image transfer conduit can be autoclaved

d.(1,2,3). Cannot be accurately determined due to inaccessibility of internal components
(4). Has thermal protector that breaks circuit after 4 min
(5). Power cord does have strain relief

e. Halogen bulb with spectral output of 400 to 500 nm

f. One-year warranty, except for bulb

g. Unit is very small and compact, and is easily mounted, but would be difficult to repair.

Unit I: Prisma-Lite

a.(1). Included with unit
(2,3). Available in near future

b. Unit is properly grounded: ground connection from molded plug to internal chassis

c.(1). Plastic molded case, cheaply made
(2). Awkward design; reassembly of plastic case difficult. Light switch on handpiece poorly designed
(3). Screw-on type connector
(4). Two to three years with normal use

d.(1). Good quality printed circuit boards
(2). Components are marked and can be cross-referenced
(3). Components inaccessible. Would require total disassembly of unit to reach internal components
(4). No fuse; externally accessible circuit breaker
(5). Power cord has strain relief

e. Tungsten-halogen bulb with spectral output of 400 to 500 nm

f. One-year warranty, except for bulb

g. Light operation requires constant pressure on switch, which could cause discomfort. Unit difficult to repair.

Unit J: Spectra-Lite

a.(1). Operator's manual included with unit
(1,2). Unavailable

b. Unit is grounded through double isolation technique; does not meet USAF standards according to AFR 160-3.

c.(1). Unit is well-made; contructed of metal
(2). Exterior design, good; inside, poor
(3). Plug-in connector
(4). Lifetime warranty under normal use

d.(1). Good quality printed circuit boards
(2). Unknown: component side of boards extremely difficult to access
(3). Much difficulty in removing and replacing components
(4). Unit has externally accessible fuse and thermal protector
(5). Detachable power cord

e. Tungsten-halogen bulb with spectral output of 400 to 500 nm

f. Lifetime warranty under normal use

g. Fiber-optic bundle offers resistance to movement. Lifetime warranty eliminates most need for maintenance.

Unit K: Translux

a.(1). Operator's manual included
(2,3). Available but not recommended by company

b. Unit properly grounded: ground connected from molded plug to internal chassis

c.(1). Sturdy, solid construction; metal cabinet
(2). Good design quality, inside and out
(3). Plug-in type connector; no light leakage
(4). Unknown. Unit does not use fiber optics, but a fluid-filled cable

d.(1). Good quality printed circuit board
(2). Components well marked and easily cross-referenced
(3). Removal of components and board is simple
(4). No fuse; externally accessible circuit breaker
(5). Detachable power cord

e. Bulb type unknown

f. A 90-day warranty on all parts

g. Light cable offers considerable resistance.

Unit L: Visar 2

a.(1). Operator manual included with unit
(2,3). Available upon demand

b. Unit is properly grounded: ground pin on molded plug connected to internal chassis

c.(1). Unit is well made; metal cabinet
(2). Good design quality
(3). Quick-disconnect plug-in type cable; no light leakage
(4). Life expectancy depends on use and care

d.(1). Good quality printed circuit board
(2). All components not marked; some could not be cross-referenced
(3). Components easily accessible
(4). Unit does not have fuse
(5). Power cord is provided with strain relief

e. Quartz-halogen bulb with spectral output of 350 to 500 nm

f. One-year warranty

g. Even though necessary literature is available, unit would be somewhat difficult to repair because components could not be cross-referenced.

On the basis of the foregoing criteria, medical maintenance personnel rated each unit on a scale of 1 to 10, with 10 being the highest rating. Ratings were the personal opinions of those evaluating the units, and are listed next:

Rating	Unit(s)
10	D
9	
8	E, F
7	K
6	C, G, H
5	L
4	J
3	I
2	B
1	A

14. Special Features

Several units (A, D, and E) have additional features that are not directly related to their curing function, but may be of some interest to potential users:

Unit A. Command: The light delivery rod, metal half shells, and plastic ring can be removed and sterilized by any method (chemical vapor, steam autoclave, or dry heat). Also, an automatic warning system signals by intermittent flashing when the bulb is about to fail.

Unit D. Heliomat: This unit has a series of filters that can be rotated in front of the light source to produce outputs of different wavelengths: (1) Polymerization; (2) Diagnostic--three intensities of cool white light for illumination and transillumination; (3) Non-curing diagnostic--a yellow light that inhibits the surface hardening that can occur under a dental operating light; (4) Plaque light--a "black" light (actually violet) that, when used with fluorescent solutions, will disclose bacterial plaque; and (5) Contrast light--a green light to aid in the examination of lesions and the detection of flash when finishing composites.

Unit E. The Initiator: Delay (dwell) time and loudness of the audible tone can be internally adjusted by operating controls on the printed circuit board. Dwell time can be set from zero to 10 sec. This unit can also be used for other purposes by changing filters that thread onto the tip of the curing wand: a clear filter gives a high intensity white light for illumination; a green filter, a contrasting light; and a red filter, a light for "deep cure" restorations.

USE AND SELECTION OF EQUIPMENT

The selection of a visible-light resin curing unit depends almost entirely upon the needs of the respective dental clinic. If resin curing capability is required for all general dentists, then a fixed unit is very practical. If a portable unit is needed, many are available. All units tested performed in essentially the same manner, except for minor differences in curing times. Cost, design, quality of construction, ease of repair, size, and portability, as well as depth of cure should be weighed according to local demands.

Even though the potential for retinal damage appears minimal, we recommended that the operator, assistant, and patient not view the light while in operation. This precaution will reduce the opportunity for distracting afterimages and momentary "flash blindness." Laser goggles will provide added protection and comfort.

Although this discussion primarily concerned the units themselves and not clinical techniques for placing light-cured resins, one observation is pertinent regarding depth of cure. To insure complete polymerization, clinicians may want to consider a layering technique during placement. An alternative is curing from multiple directions for 20 to 30 sec per exposure.

Any questions concerning this Aeromedical Review should be directed to the Dental Investigation Service, USAFSAM/NGD, Brooks AFB TX 78235, AUTOVON 240-3502; Commercial (512) 536-3502.

TABLE 1. COMPARISON OF SELECTED FEATURES OF VISIBLE-LIGHT RESIN CURING UNITS

Unit	Price	Timer	Method of light transmission	Depth of cure (time for 2-mm cure)	Hazard time-blue light/thermal hazards	Maintenance rating
A	$343.98	10 to 30 sec	Fiber optics	30 sec	8.9 min/31 min	1
B	$486.85	Auto shut off 20 sec	Glass rod	20 sec	7.9 min/2+ hr	2
C	$198.00	No timer	Fiber optics	30 sec	4.3 min/6.0 min	6
D	$499.15	10 sec to infinity	Fiber optics	30 sec	10.5 min/2+ hr	10
E	$350.00	10 to 60 sec	Fiber optics	50 sec	N/A	8
F [a]	$219.00	2 to 60 sec	Fiber optics	40 sec	12.0 min/6.5 min	8
G	$479.00		Fiber optics	40 sec	7.8 min/5.7 min	6
H	$409.50	Tone q,10 sec	Glass rod	20 sec	2.4 min/23 min	6
I	$400.00	Tone q,10 sec	Fiber optics	30 sec	6.2 min/2 hr	3
J	$450.00	10 sec to infinity	Fiber optics	30 sec	13.0 min/2 hr	4
K	$500.00	Tone q,20 sec	Fluid-filled cord	30 sec	31.0 min/1 hr	7
L	$362.50	Tone q,20 sec	Fiber optics	30 sec	2 hr/47 min	5

[a] Cost to retrofit existing light source

REFERENCES

1. Measurement of the radiation emissions from the NUVA-LITE dental appilance. DHEW Publication (FDA) 75-8031, Apr 1975.

2. Sliney, David. Safety with lasers and other optical sources. New York: Plenum Press, 1980, pp. 325-345.

3. Symposium on composite resins in dentistry. Dent Clin N Am 25(2):1-378 (Apr 1981).

I L L U S T R A T I O N S

Figure Nos. 1 - 25

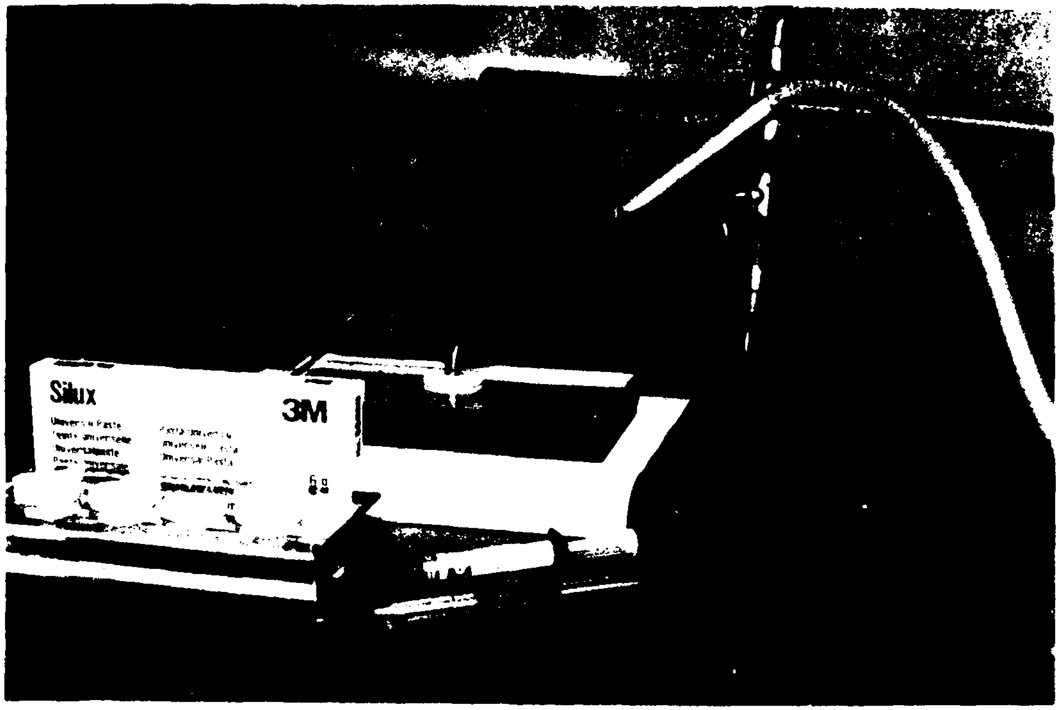


Figure 1. Equipment and materials for depth of cure testing.

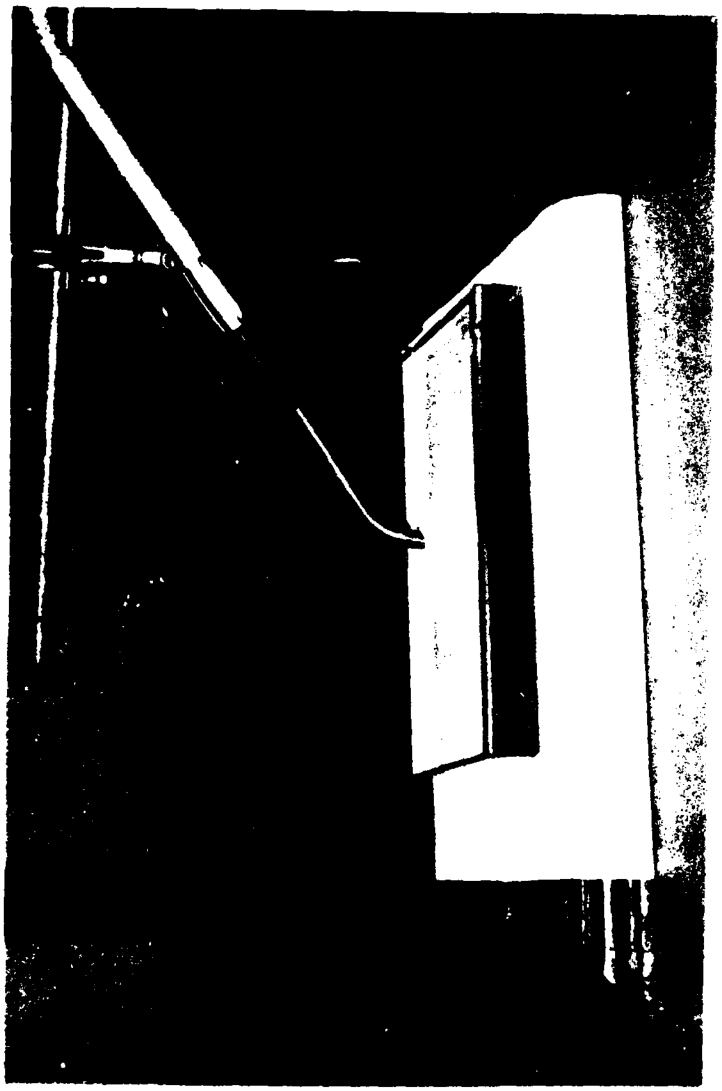
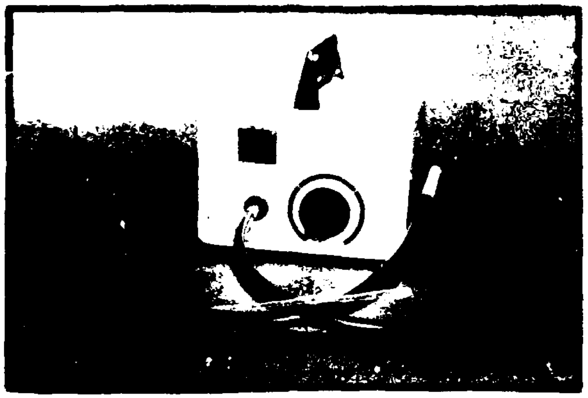
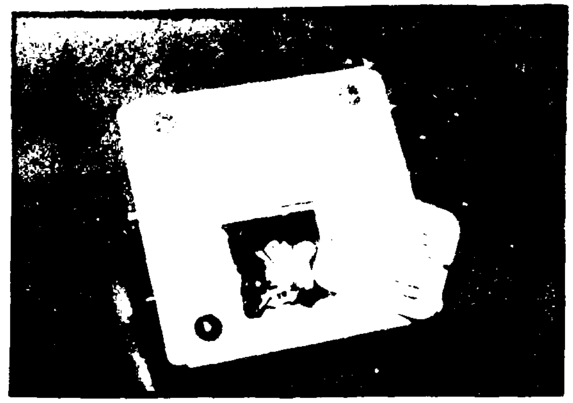


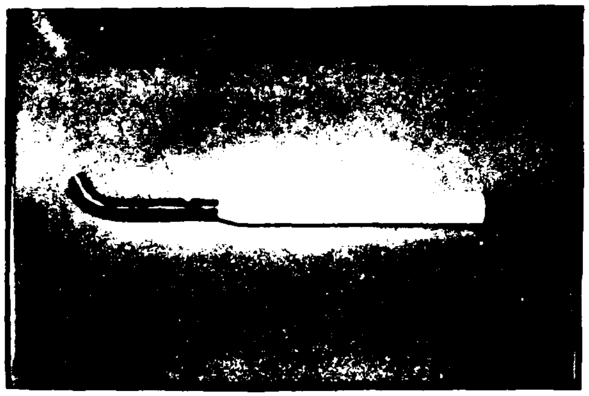
Figure 2. Positioning of light wand for depth of cure testing.



(a)



(c)



(b)

Figure 3. Unit A: Command (Kerr Manufacturing).
(a) Unit
(b) Curing Wand
(c) Method of changing bulb

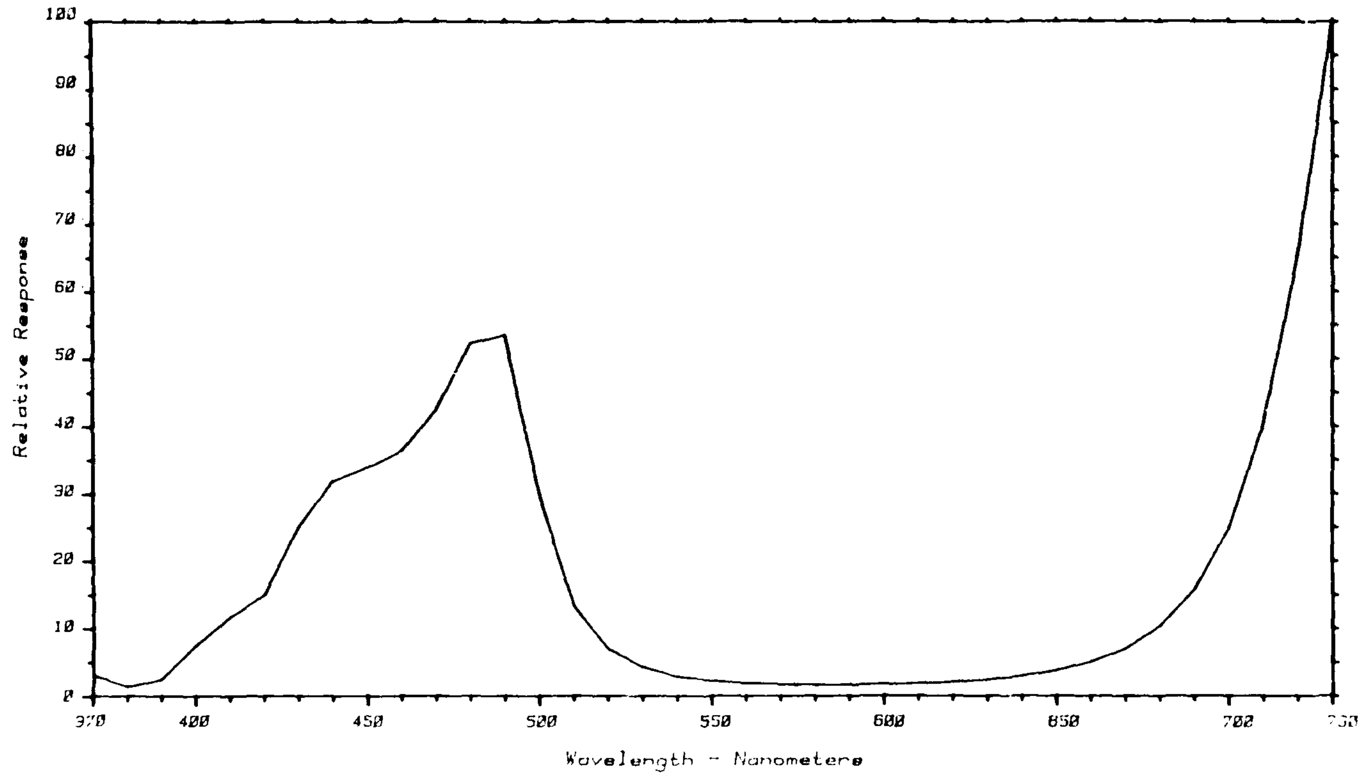
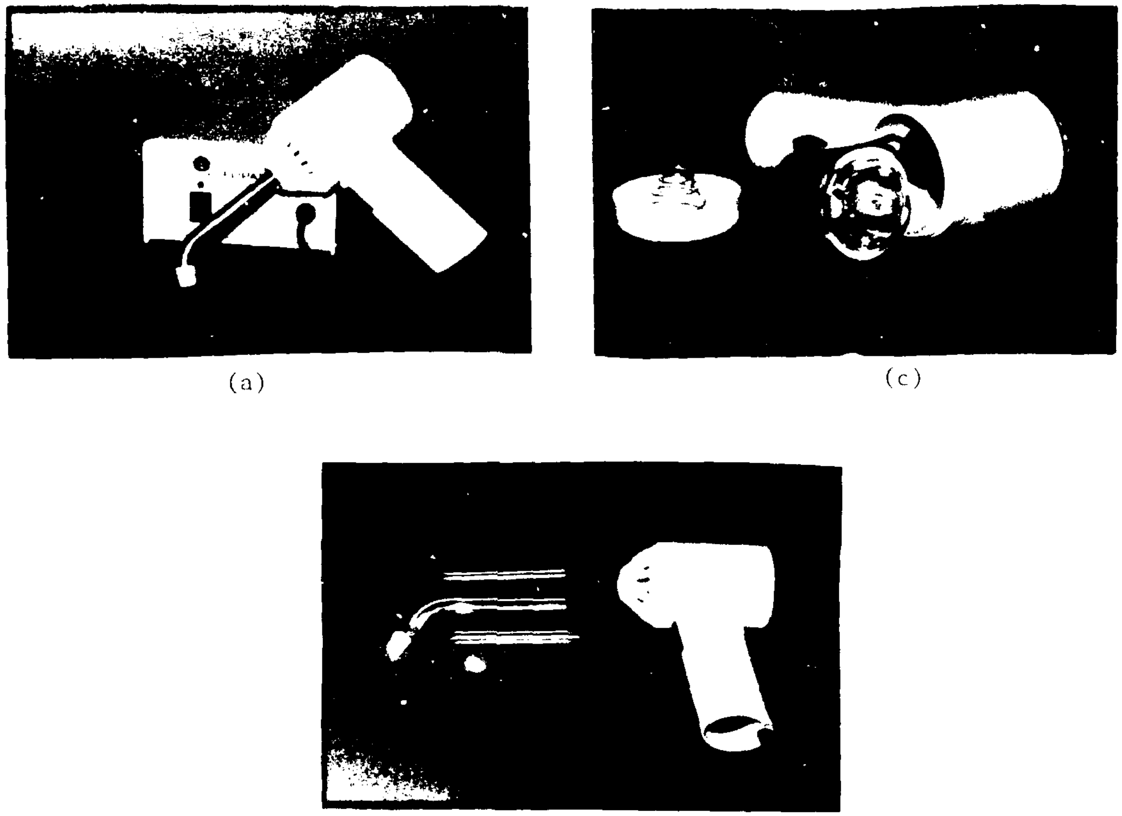


Figure 4. Unit A: Command (Kerr Manufacturing)--Wavelength distribution, with peak at 730 nm.



(a) (c)

(b)

Figure 5. Unit B: Elipar (ESPE-Premier).
(a) Unit
(b) Curing Wand
(c) Method of changing bulb

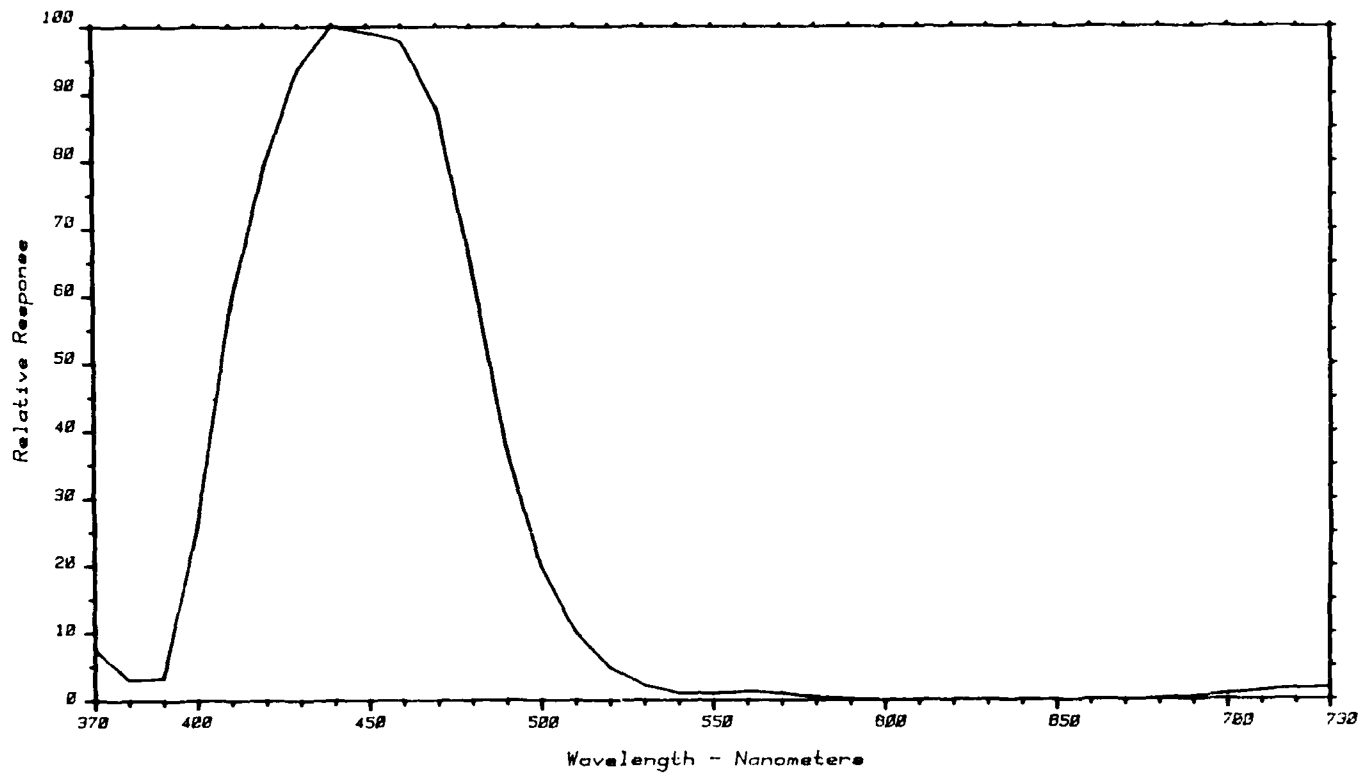
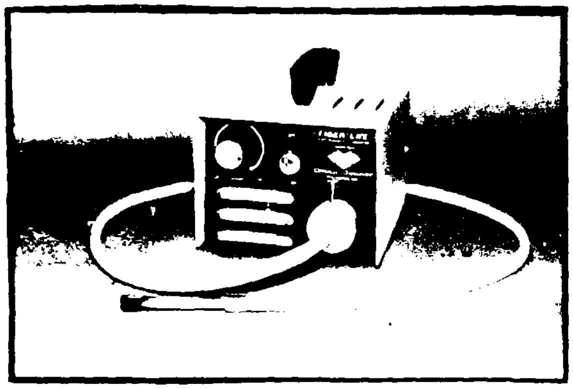
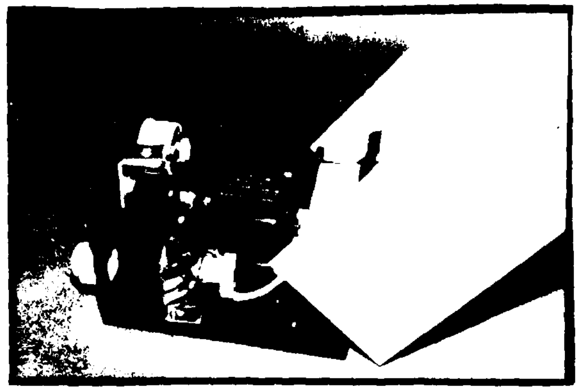


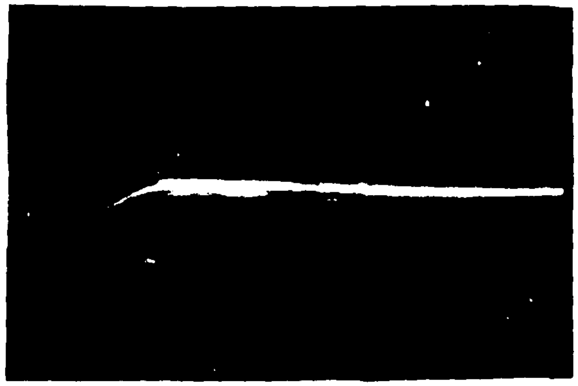
Figure 6. Unit B: Elipar (ESPE-Premier)--Wavelength distribution, with peak at 440 nm.



(a)



(c)



(b)

Figure 7. Unit C: Fiber-Lite (Dolan-Jenner Industries).
(a) Unit
(b) Curing Wand
(c) Method of changing bulb

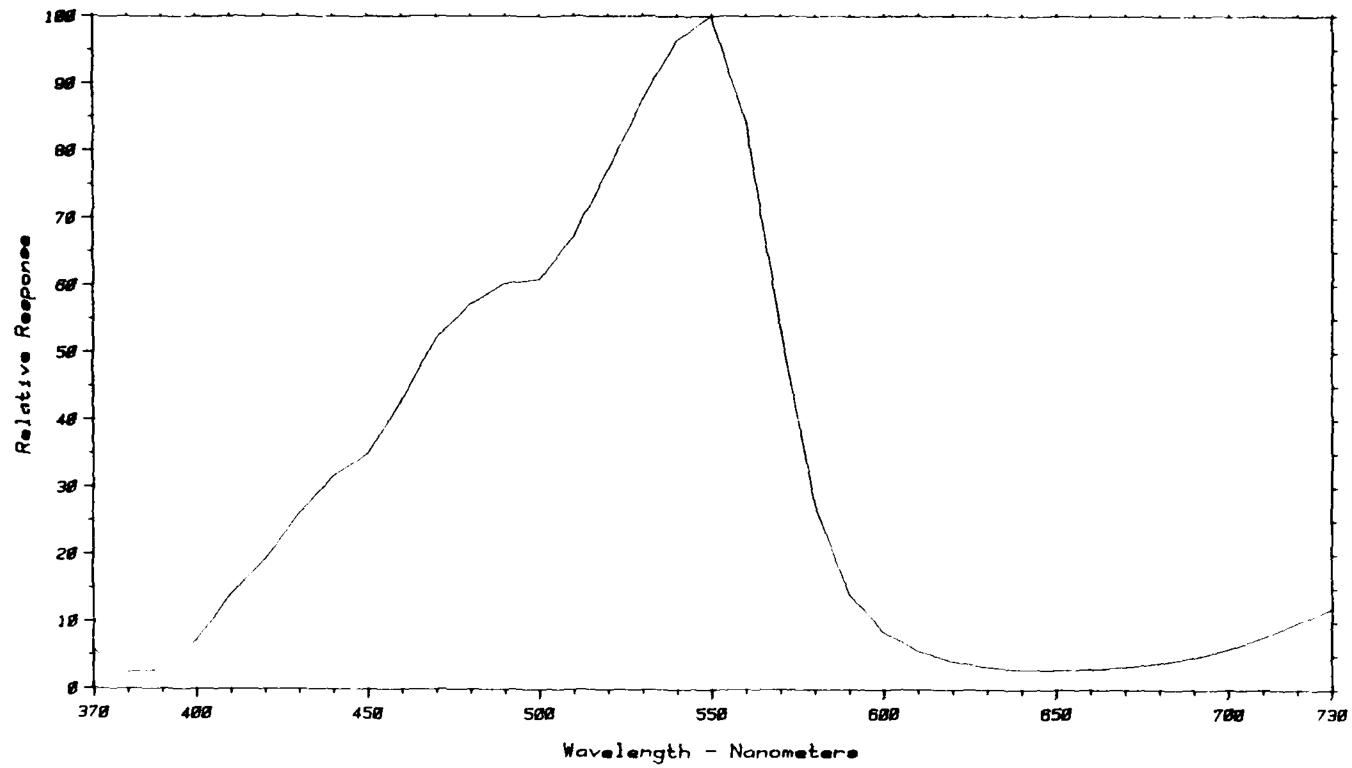
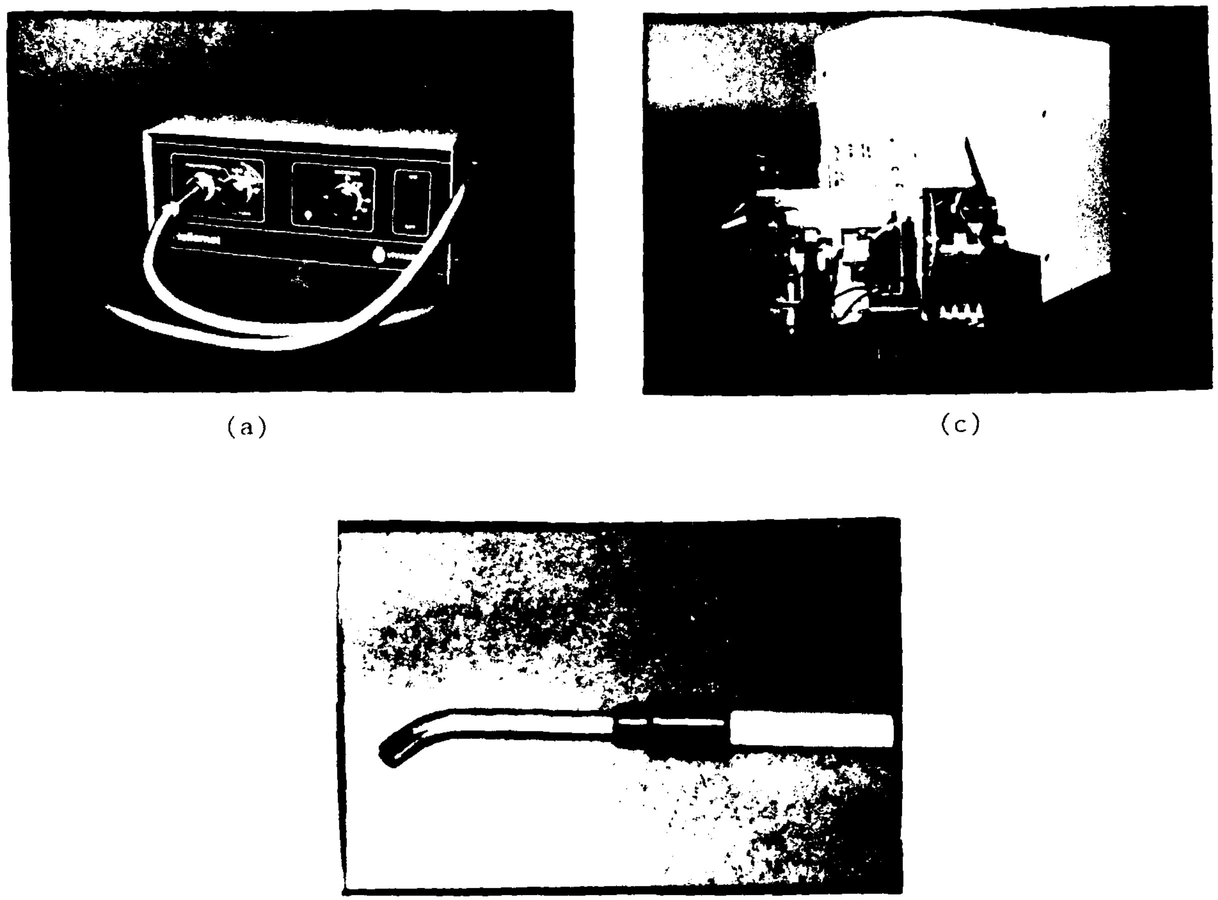


Figure 8. Unit C: Fiber-Lite (Dolan-Jenner Industries)--Wavelength distribution, with peak at 550 nm.



(a) (c)

(b)

Figure 9. Unit D: Heliomat (Vivadent USA).
(a) Unit
(b) Curing Wand
(c) Method of changing bulb

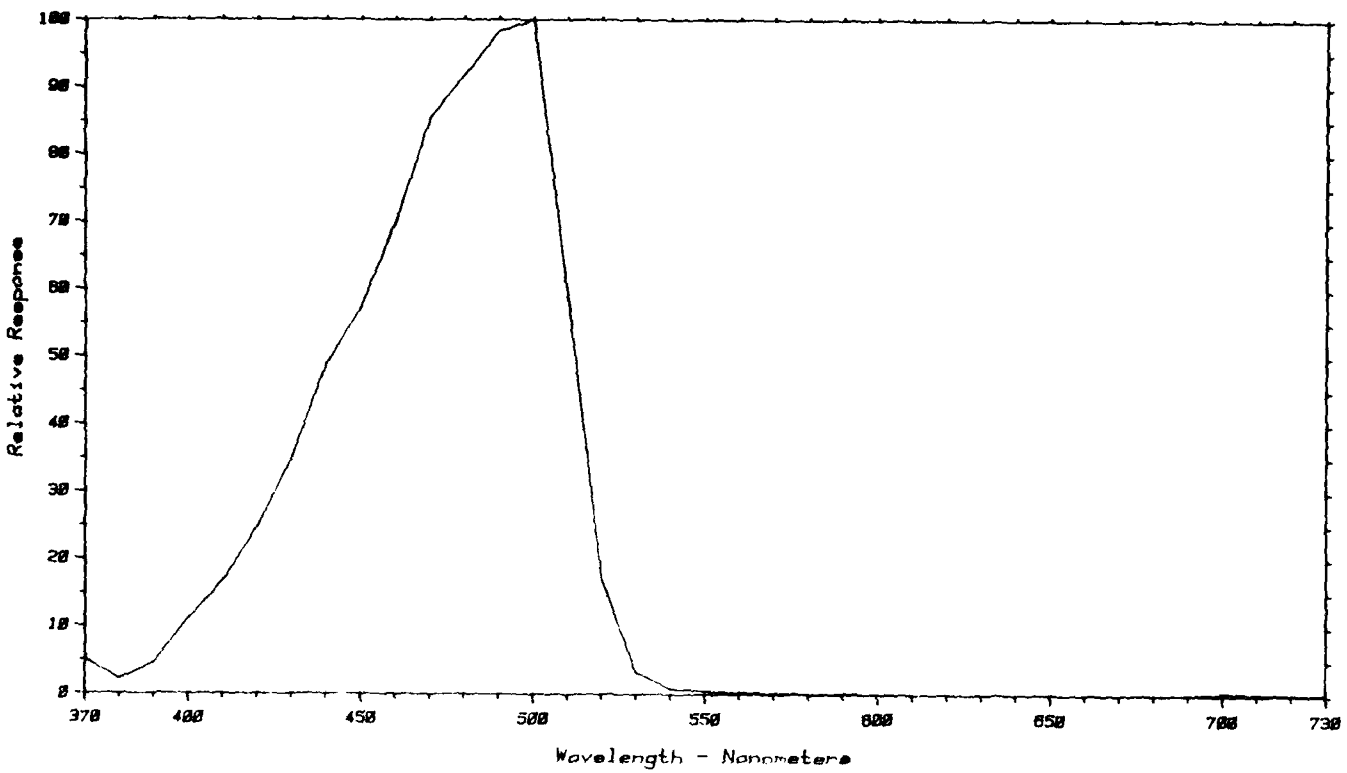
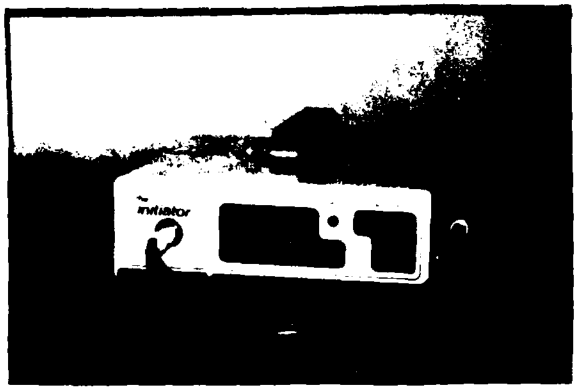
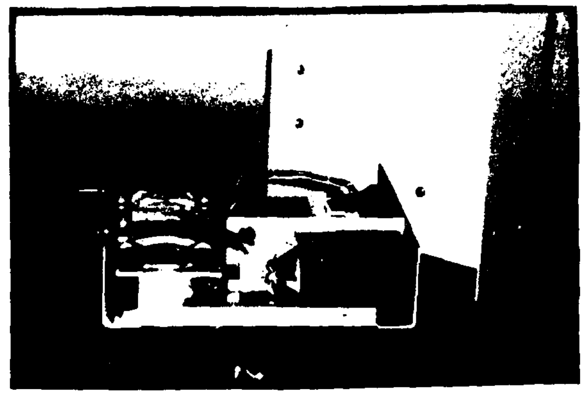


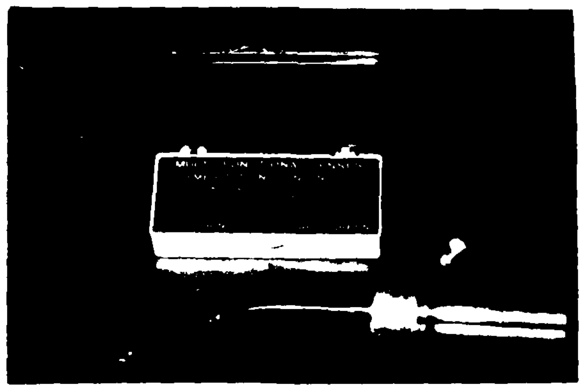
Figure [illegible]. Unit E: Heliomat (Vivadent USA)--Wavelength distribution, with peak at 500 nm.



(a)



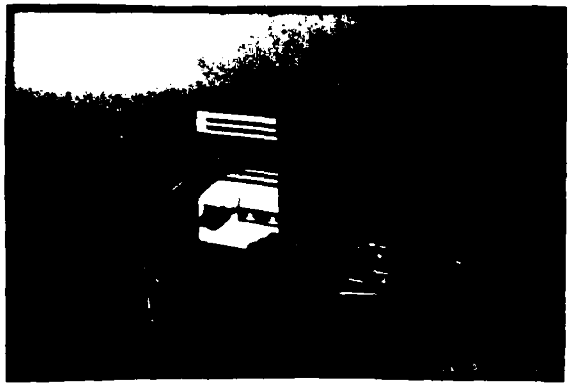
(c)

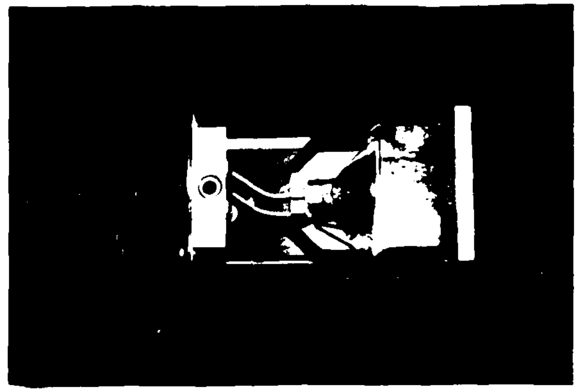


(b)

Figure 11. <u>Unit E</u>: The Initiator (Solid State Systems).
(a) Unit
(b) Curing Wand
(c) Method of changing bulb

[EDITOR'S NOTE: For Unit E, no spectroradiometric graph showing wavelength distribution is available.]


(a)


(c)


(b)

Figure 12. Unit F: Insight II (American Midwest).
(a) Unit
(b) Curing Wand
(c) Method of changing bulb

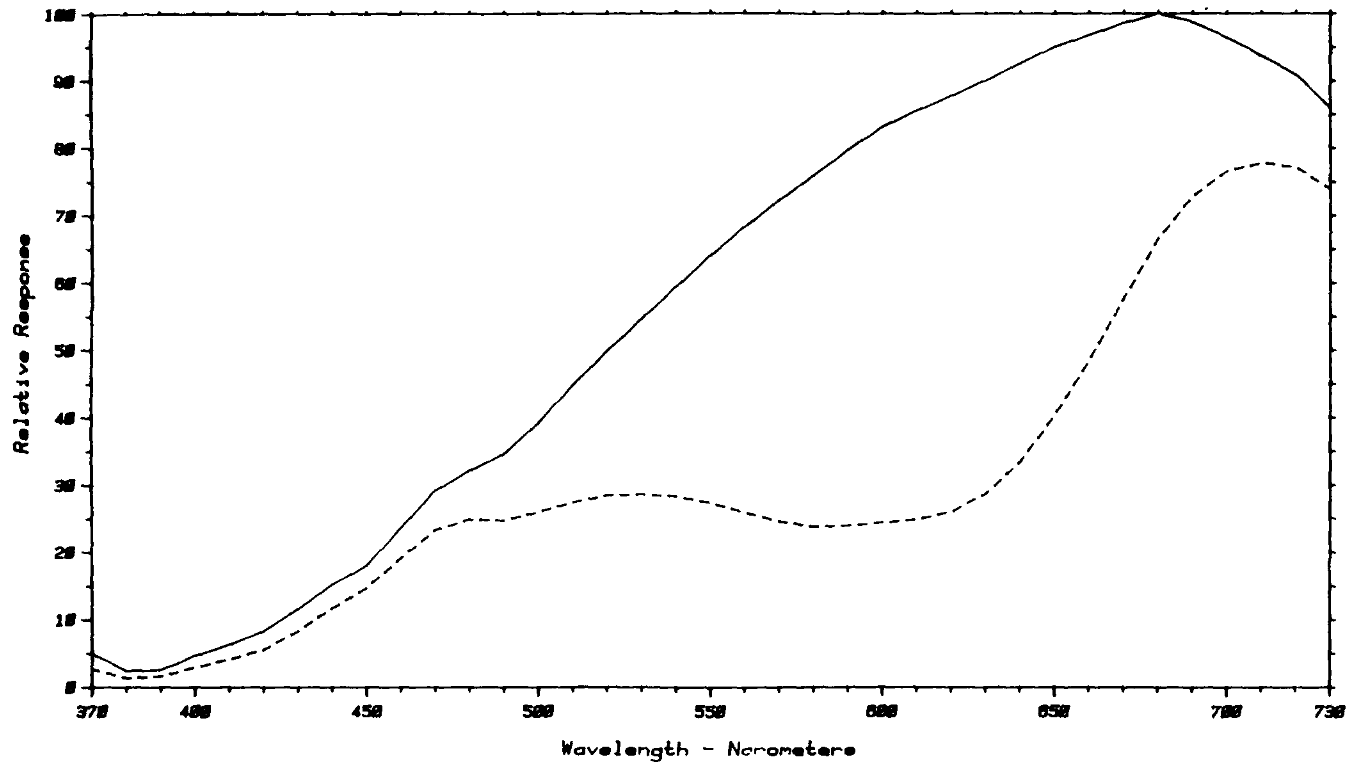
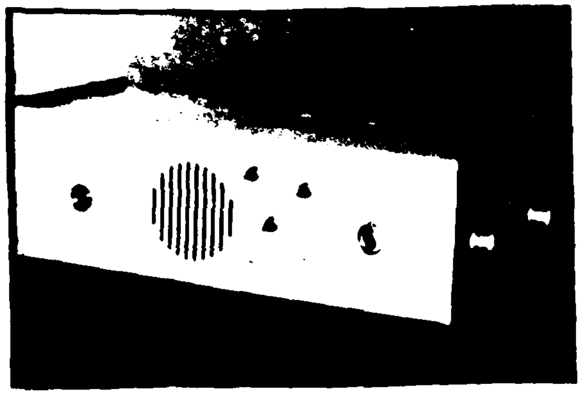
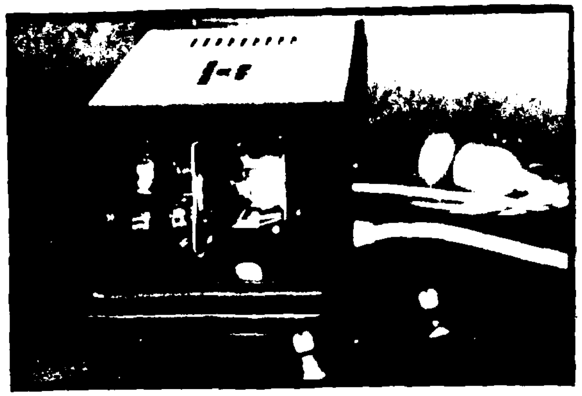


Figure 13. Unit F: Insight II (American Midwest)--Wavelength distribution, with peak at 680 nm without blue cap (——); and peak at 710 nm with blue cap (---).



(a)



(c)

(b)

Figure 14. Unit G: Kavo/Vicon "DLS" (Kavo American Corporation).
(a) Unit
(b) Curing Wand
(c) Method of changing bulb

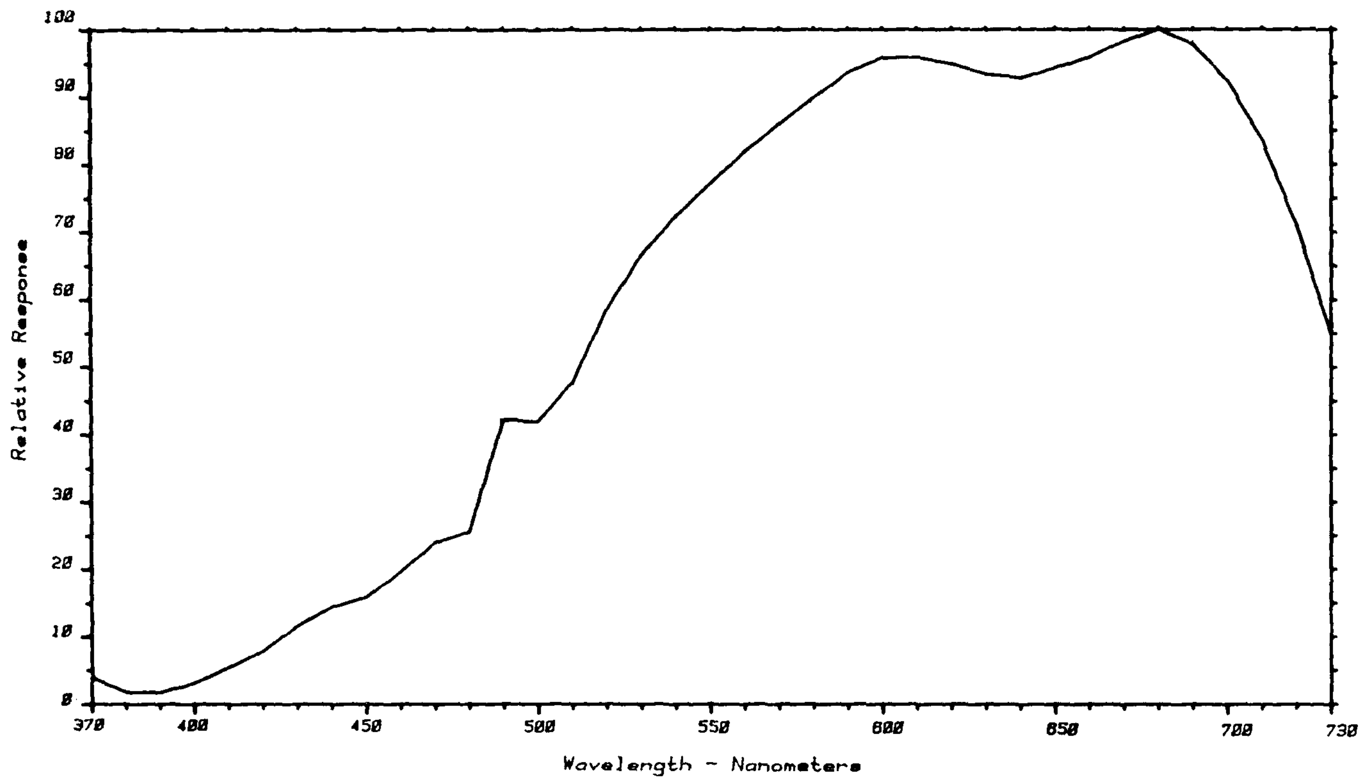
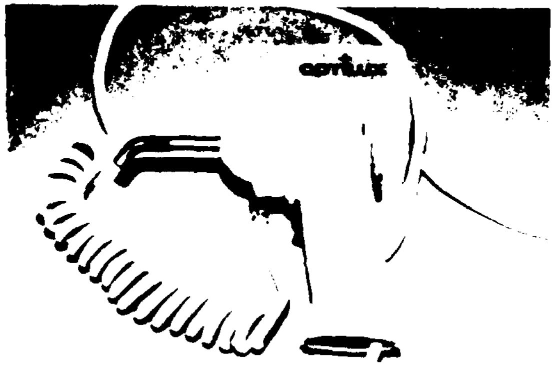
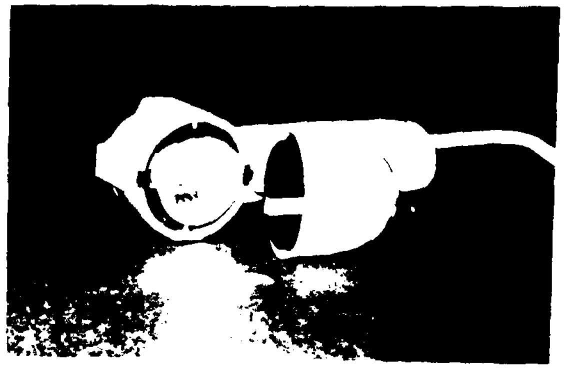


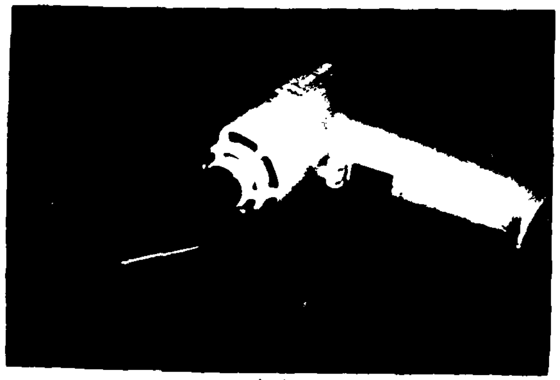
Figure 15. Unit G: Kavo/Vicon "DLS" (Kavo American Corporation)--Wavelength distribution, with peak at 680 nm.



(a)



(c)



(b)

Figure 16. Unit H: Optilux (Demetron Research Corporation).
(a) Unit
(b) Curing Wand
(c) Method of changing bulb

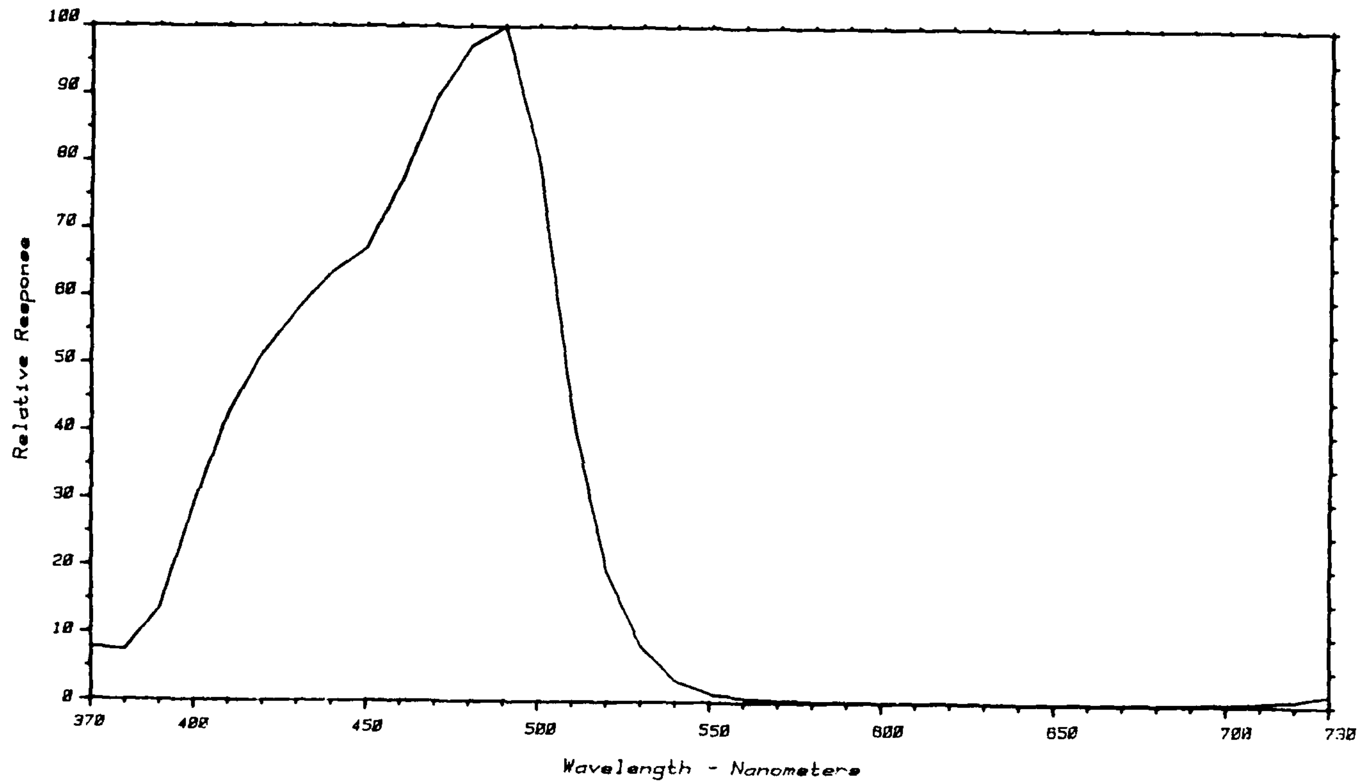
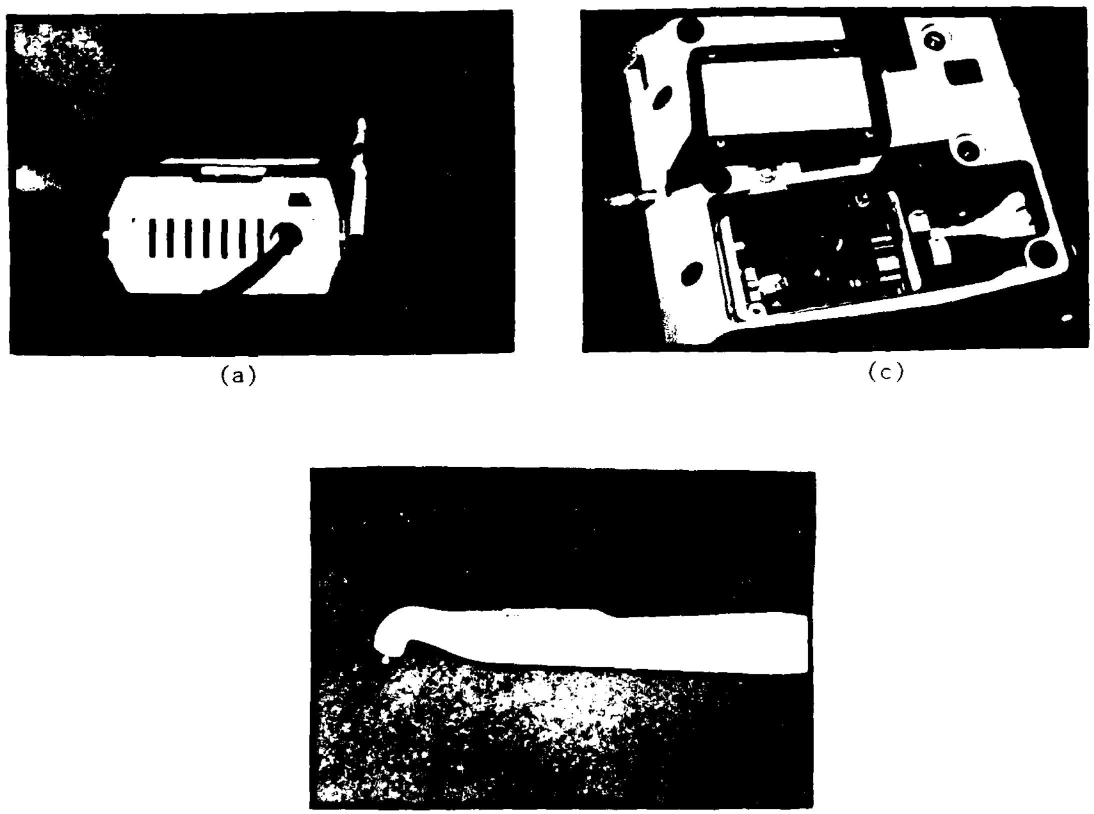


Figure 17. Unit H: Optilux (Demetron Research Corporation)--Wavelength distribution, with peak at 490 nm.



(a) (c)

(b)

Figure 18. Unit I: Prisma-Lite (L. D. Caulk).
(a) Unit
(b) Curing Wand
(c) Method of changing bulb

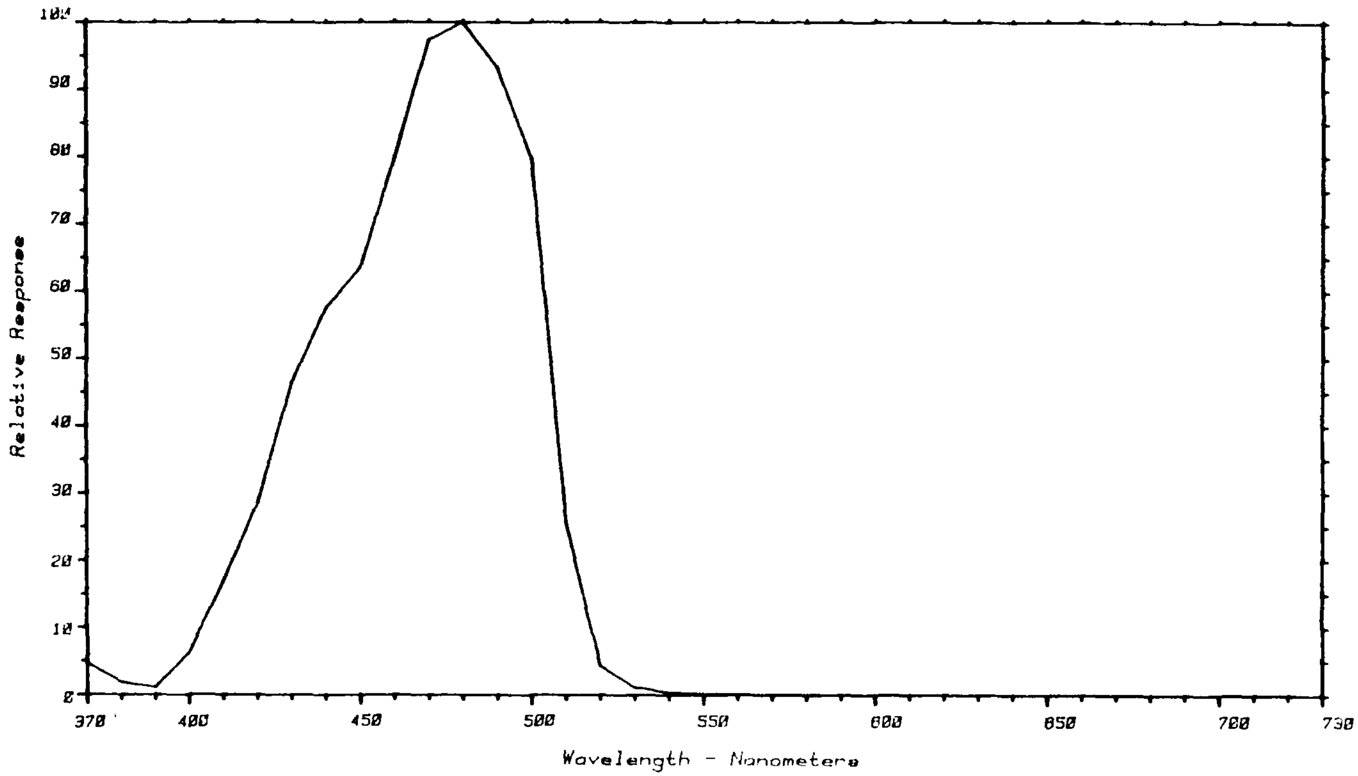
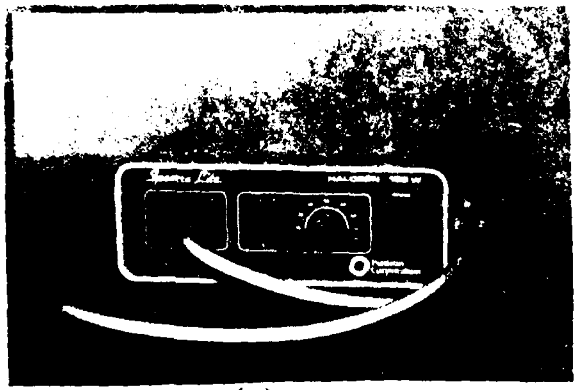
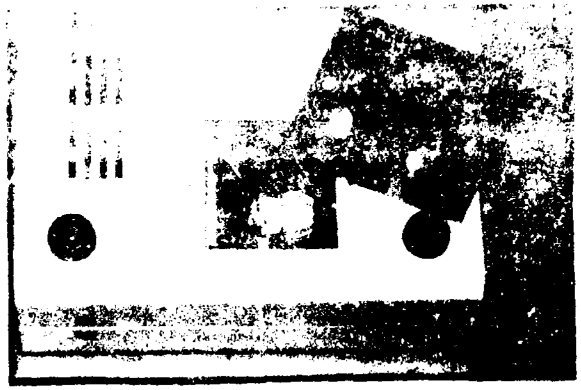


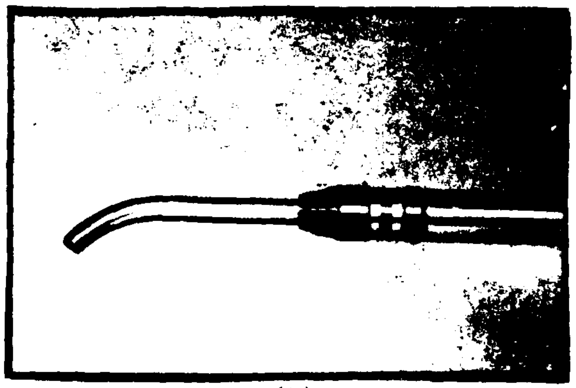
Figure 19. Unit I: Prisma-Lite (L. D. Caulk)--Wavelength distribution, with peak at 480 nm.



(a)



(c)



(b)

Figure 20. Unit J: Spectra-Lite (Pentron Corp.)
(a) Unit
(b) Curing Wand
(c) Method of changing bulb

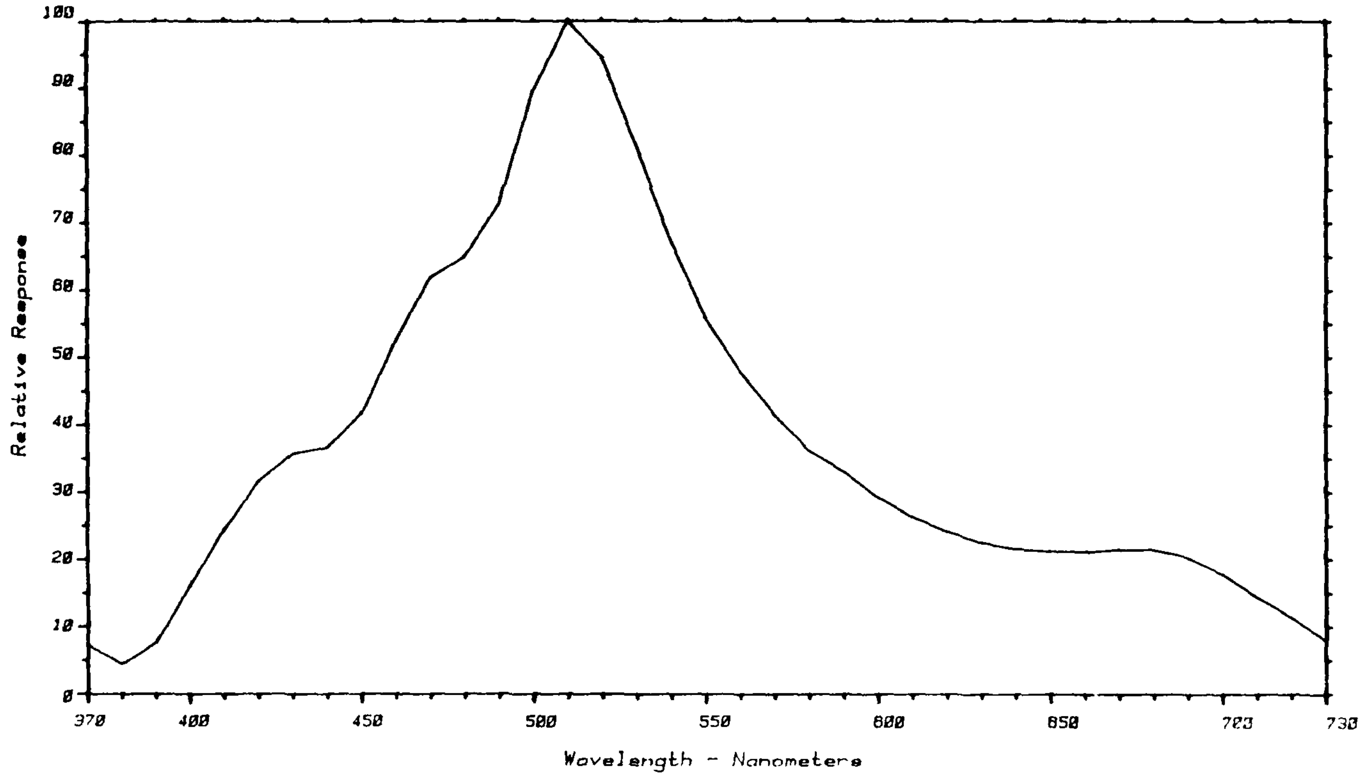
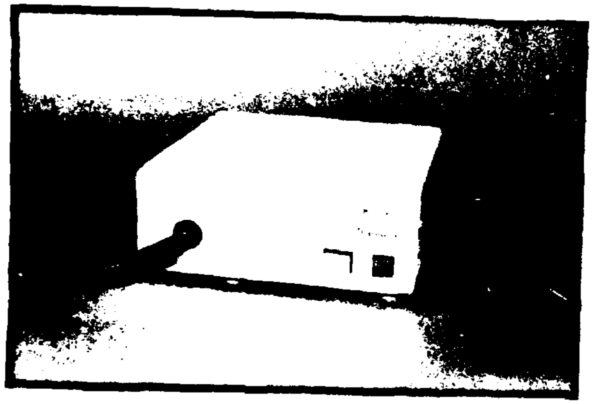


Figure 21. Unit J: Spectra-Lite (Pentron Corp.)--Wavelength distribution, with peak at 510 nm.



(a)

NOT AVAILABLE

(c)

NOT AVAILABLE

(b)

Figure 22. Unit K: Translux (Kulzer, Inc.).
(a) Unit
(b) Curing Wand
(c) Method of changing bulb

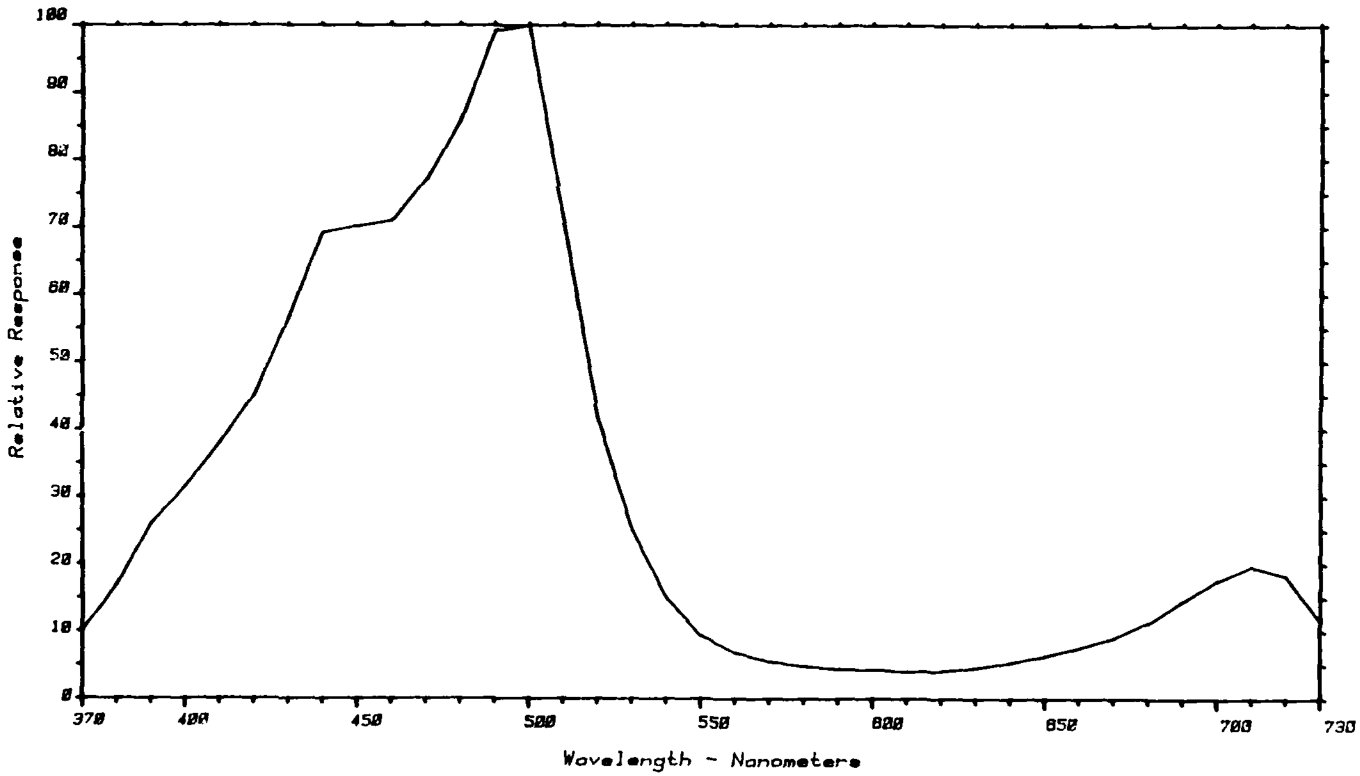
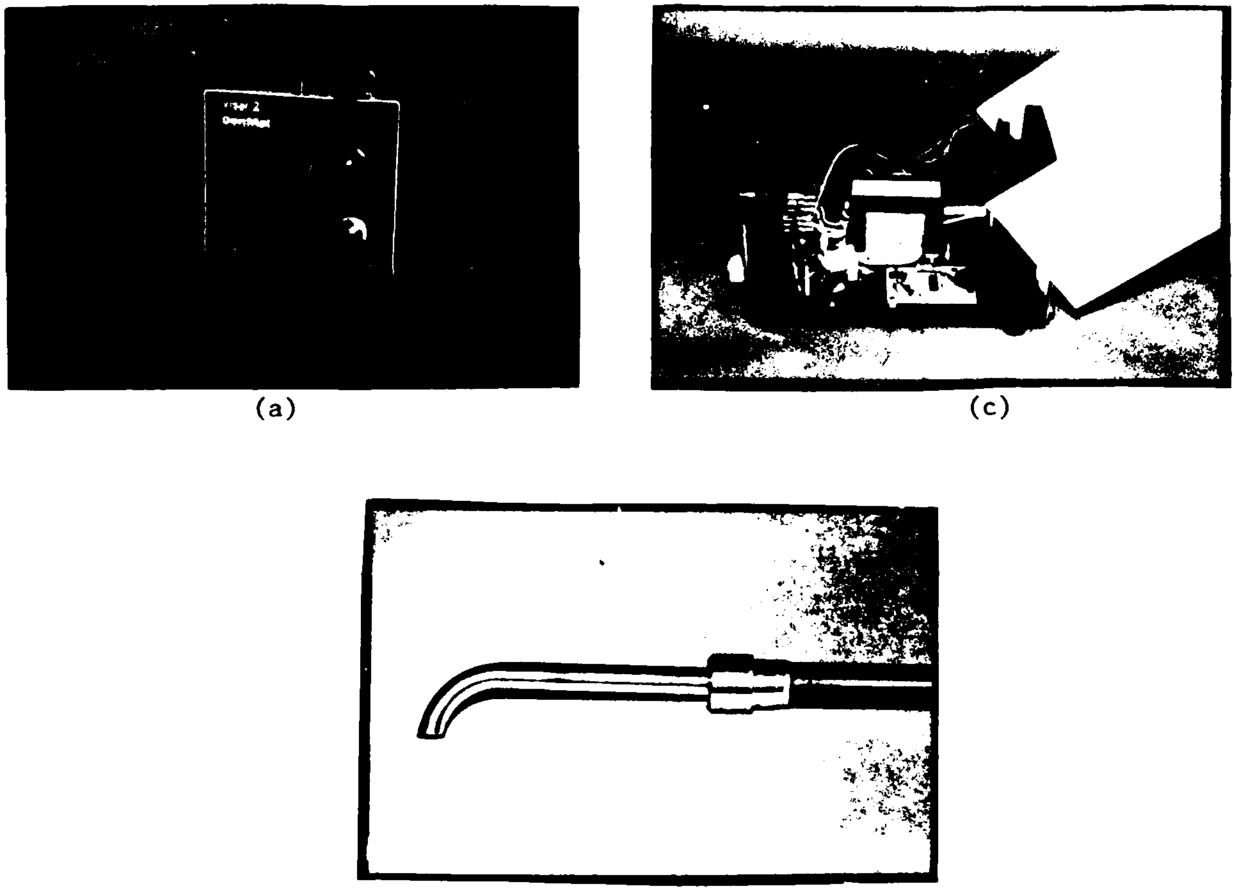


Figure 23. Unit K: Translux (Kulzer, Inc.)--Wavelength distribution, with peak at 500 nm.



(a) (c)

(b)

Figure 24. Unit L: Visar 2 (Den Mat).
(a) Unit
(b) Curing Wand
(c) Method of changing bulb

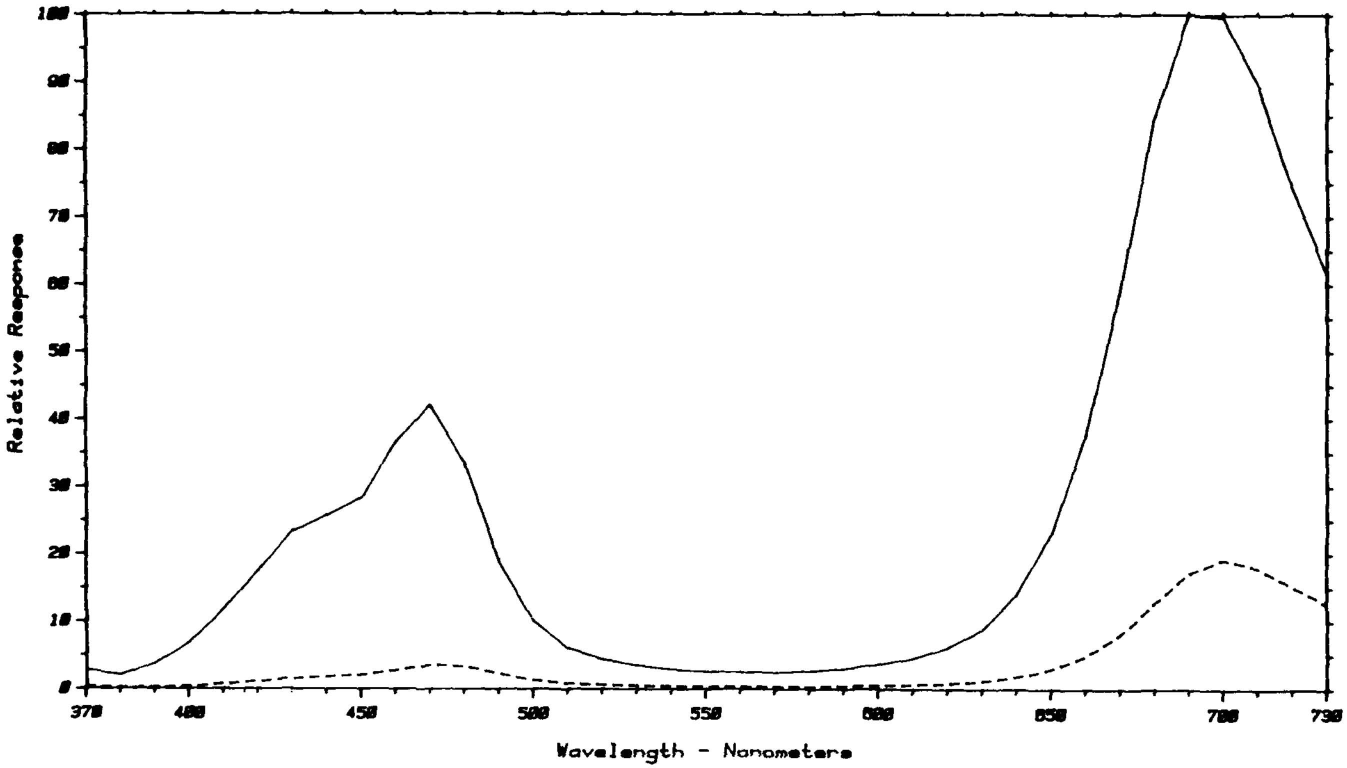


Figure 25. Unit L: Visar 2 (Den Mat)--Wavelength distribution, with peaks at 600 nm (high intensity level,——); and at 700 nm (low intensity level, ---).

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